# POWER

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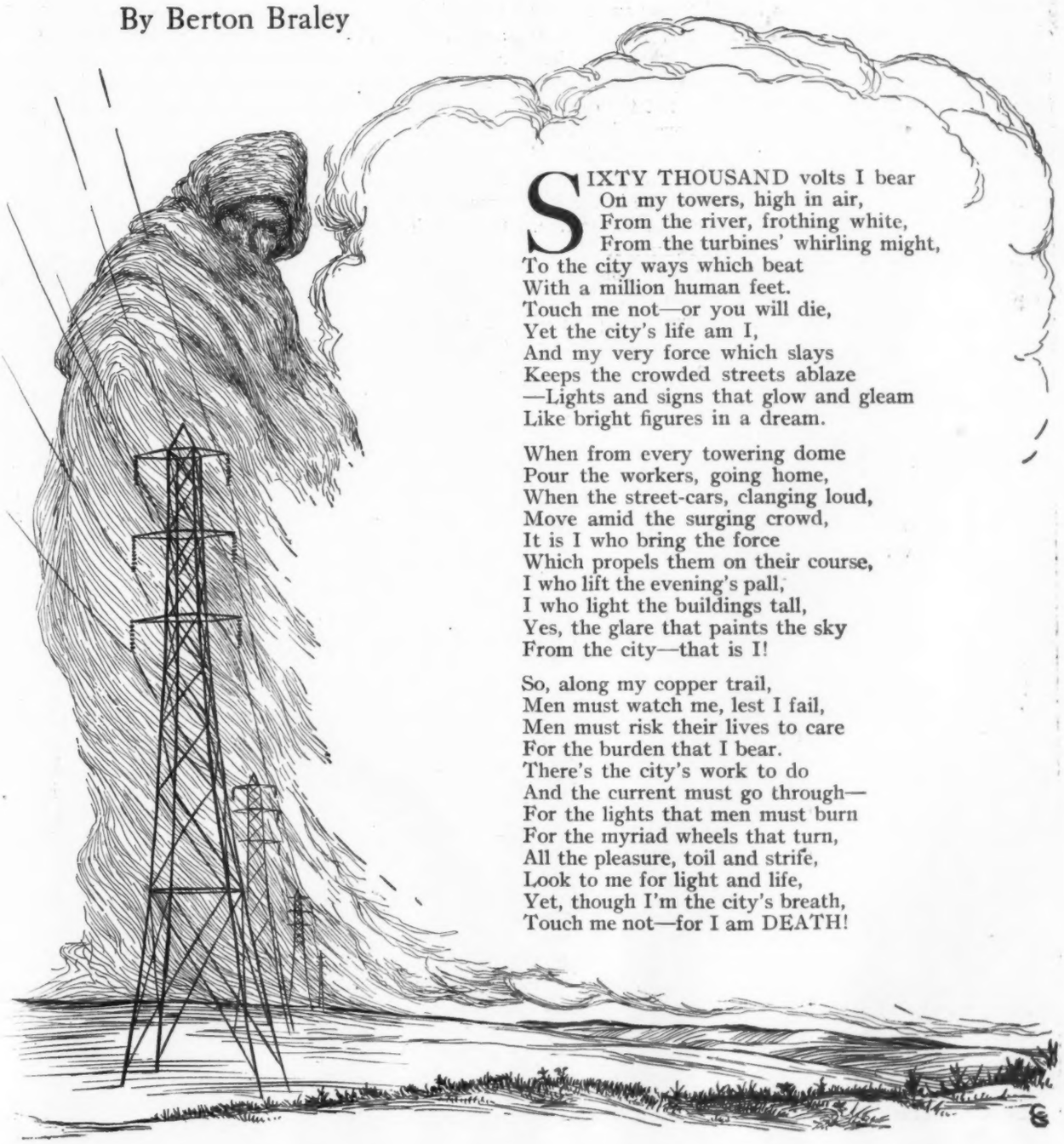
# THE TRANSMISSION LINE

By Berton Braley

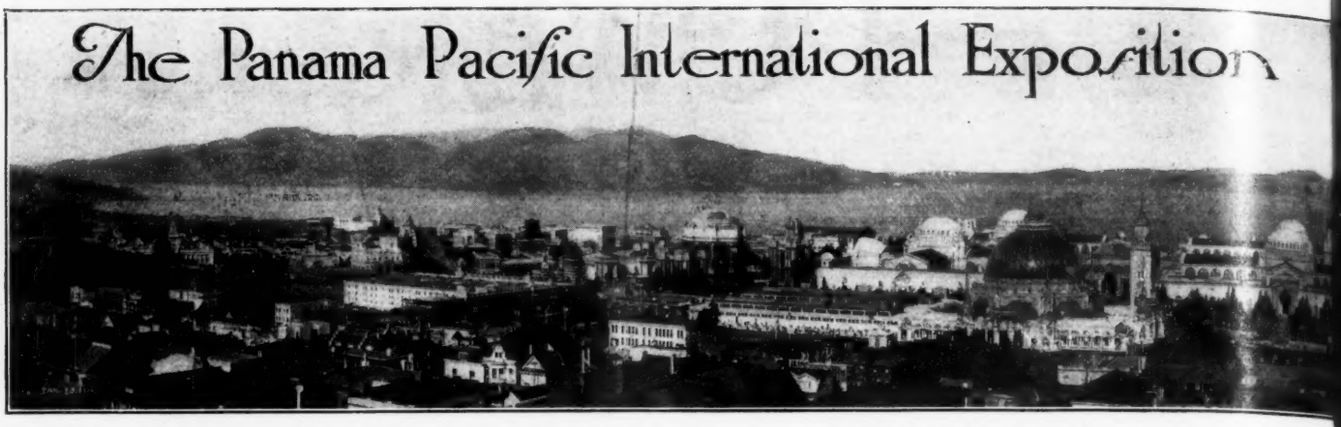


SIXTY THOUSAND volts I bear
On my towers, high in air,
From the river, frothing white,
From the turbines' whirling might,
To the city ways which beat
With a million human feet.
Touch me not—or you will die,
Yet the city's life am I,
And my very force which slays
Keeps the crowded streets ablaze
—Lights and signs that glow and gleam
Like bright figures in a dream.

When from every towering dome
Pour the workers, going home,
When the street-cars, clanging loud,
Move amid the surging crowd,
It is I who bring the force
Which propels them on their course,
I who lift the evening's pall,
I who light the buildings tall,
Yes, the glare that paints the sky
From the city—that is I!

So, along my copper trail,
Men must watch me, lest I fail,
Men must risk their lives to care
For the burden that I bear.
There's the city's work to do
And the current must go through—
For the lights that men must burn
For the myriad wheels that turn,
All the pleasure, toil and strife,
Look to me for light and life,
Yet, though I'm the city's breath,
Touch me not—for I am DEATH!

# The Panama Pacific International Exposition




Third of its class held in the United States and twelfth of its class held anywhere in the world, the Panama-Pacific Exposition was officially opened when President Wilson touched the button last Saturday. Contrary to the usual international expositions, it is not the celebration of an anniversary of some past event, but commemorates a modern achievement—the completion of the Panama Canal. In its exhibits it is intended to show particularly the advance which has been made in the last ten years, or since the Louisiana Purchase Exposition. There being less of history in it than is usual, it is especially interesting to contrast some things contemporaneous with the years of the various World's Fairs. For example, in the steam-power field, we have, as typical of their respective times, the big Corliss walking-beam engine at the Centennial Exposition at Philadelphia in 1876, the quadruple-expansion 2000-hp. Corliss engine at the Columbian Exposition at Chicago in 1893, a 5000-hp. angle compound engine and a steam turbine of 2000 kw. at the Louisiana Purchase Exposition at St. Louis in 1904, with turbines as large as 5000 kw. built at that time, and now 35,000-kw. turbines, though none of that size will be exhibited at San Francisco, for the Panama-Pacific Exposition does not generate its own power for lighting and the operation of moving exhibits, but purchases its current from the Pacific Gas & Electric Co. which has over 90,000 kw. in hydro-electric installations and approximately 100,000 kw. in steam installations, the steam plants being boosters or auxiliaries in case of breakdown of the hydro-electric stations. Three-phase, 60-cycle, alternating current of 11,000 and 4000 volts will be furnished in amount up to 9000 kw. between 5 and 7:30 in the afternoon of any day or up to 15,000 kw. at any other time. The 18,000 kw. steam plant of the Sierra & San Francisco Power Co. is held in reserve, ready in case of interruption of the Pacific Gas & Electric service. The exposition's secondary distribution is at various voltages—117 for lighting, and 230 and 440 for power. Direct current by conversion through motor generators is available at 250-125 volts. The Centennial engine drove the machinery by means of lineshafts gear-driven from the engine and extending throughout the building.

FRONT END OF THE PALACE OF MACHINERY

## THE CENTENNIAL ENGINE

This engine was really a pair of beam-engines and formed the most prominent exhibit at the Centennial. They operated condensing and were supplied with steam at 80 lb. pressure. The valves and valve-gears were Corliss and the cylinders were 40 in. in diameter with 10-ft. stroke. The beams were 27 ft. long by 9 ft. deep and weighed 11 tons each. They were connected at right angles to a shaft carrying the flywheel, which was a cut gear wheel 30-ft. diameter and 2-ft. face, and was the heaviest cut wheel that had ever been made up to that time. It geared with a 10-ft. pinion on an underground shaft 256 ft. long running across the building. This lineshaft at each end and two intermediate points was connected by 6-ft. bevel gears to transverse shafts extending lengthwise of the building. These shafts were belted to eight overhead shafts, each 658 ft. long. The engine made 36 r.p.m., giving a piston speed of 720 ft. per min. The peripheral speed of the spur gears was 3384 ft. per min. The engines were rated at 1400 hp., but could develop 2000. The cylinders were jacketed with live steam.

Steam was supplied by twenty vertical boilers furnished by Corliss, which also supplemented the steam supply to the Pump Annex. Each boiler contained 48 tubes 3 in. in diameter in a shell 4 ft. in diameter by 14 ft. high. The total heating surface of the twenty boilers was given as 13,000 sq.ft.

### Columbian Fair Engines

A heterogeneous collection of engines was to be seen at Chicago—horizontal and vertical, high-speed and low-speed—and no one type can be taken as representative of that time. The largest engine shown was a 2000-hp. Allis (Reynolds-Corliss) engine with 20-, 40-, 60- and 70x 72-in. cylinders and 60 r.p.m. The flywheel was 30 ft. diameter by 76-in. face and carried two belts 6 ft. wide, each driving a Westinghouse 10,000-incandescent-light dynamo. Another notable engine was the 1250-hp. four-cylinder triple-expansion Buckeye engine with its distinctive valve-gear. Its cylinders were 20, 32 and 36x48 in. The flywheel was 20-ft. diameter by 72-in. face and it also

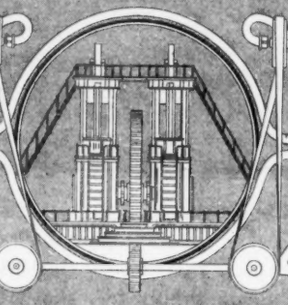
Vestibule to the Palace of Machinery

# MACHINERY BUILDINGS
## PHILADELPHIA 1876

**POWER TRANSMISSION**

Source: One 1400-hp. slow-speed Corliss engine in the center of one of the main bays.

Transmission by one main line of underfloor shafting, 352 ft. long and 8 overhead lengthwise shafts each 624 ft. long. The intermediate jackshafts were driven through 6-ft. bevel gears.



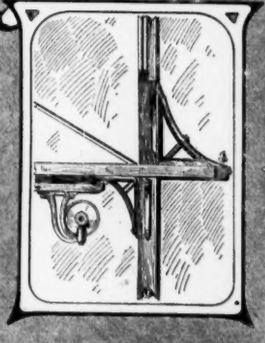
**MATERIALS of CONSTRUCTION**

| | |
|---|---|
| STONE | 15,000,000 Lb. |
| LUMBER | 5,000,000 Bd. Ft. |
| WROUGHT IRON | 760,000 Lb. |
| TIN ROOFING | 700,000 Sq. Ft. |
| CAST IRON | 500,000 Lb. |
| GLASS | 175,000 Sq. Ft. |
| NAILS | 20,000 Lb. |

Constructed with brick curtain walls, square timber columns and wrought-iron roof trusses

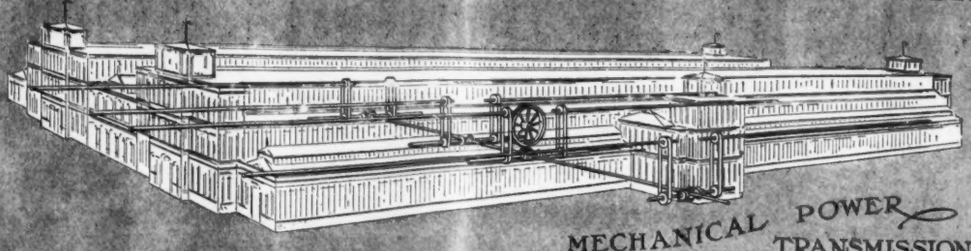
LENGTH 1402 FT. WIDTH 360 FT. AREA 13 ACRES COST $ 634,863

CENTENNIAL MACHINERY HALL



POST DETAILS and SHAFT HANGER

HANDLING MATERIAL on SKIDS and ROLLERS



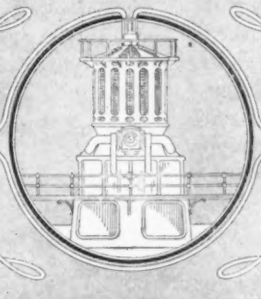
MECHANICAL POWER TRANSMISSION

# AT TWO EXPOSITIONS
## SAN FRANCISCO 1915

### MATERIALS of CONSTRUCTION

| | |
|---|---|
| PILES | 45,000 Lin. Ft. |
| LUMBER | 7,500,000 Bd. Ft. |
| BOLTS, WASHERS, Etc. | 3,000,000 Lb. |
| COMPOSITION ROOFING | 326,000 Sq. Ft. |
| GLASS | 106,000 Sq. Ft. |
| NAILS | 4 CARLOADS |

Built entirely of wood, being the largest building of mill design ever constructed.



### POWER DISTRIBUTION

Source: Two electric-power stations connected by distributing mains with all parts of the building. Total 20,000 Hp.

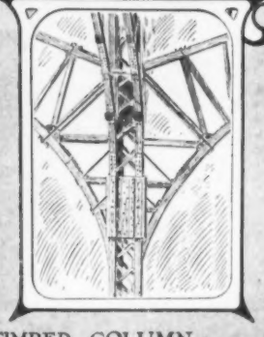
Power Circuits: Three-phase 60-cycle 230-volt and single-phase 60-cycle 117-volt.

Lighting Circuit: 60-cycle 117-volt three-wire system

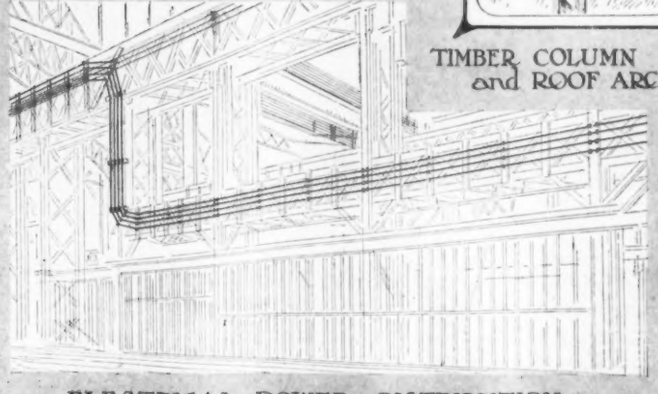
LENGTH 968 FT. WIDTH 368 FT. AREA 8.3 ACRES COST $650,000

PANAMA-PACIFIC PALACE of MACHINERY

HANDLING MATERIAL WITH OVERHEAD CRANE



TIMBER COLUMN and ROOF ARCHES



ELECTRICAL POWER DISTRIBUTION

drove through a 6-ft. belt. It has since developed that fewer cylinders and larger ratios are better and even triple-expansion engines are not warranted except with the higher pressures used in marine service.

### Louisiana Purchase Exposition Engines and Turbines

At this time (1904), the struggle between the turbine and the reciprocating engine was on and the advantage of the former, even in large units, was yet to be established. The largest turbines of their day were 5000-kw. Those exhibited were a 2000-kw. Curtis, a 1000-kw. Hamilton-Holzwarth, and a 400-kw. Westinghouse-Parsons. There were 21 engines, of which the 5000-hp. Allis-Chalmers angle compound was the largest, most impressive and most typical of the art and time. It had cylinders 44 and 94x60 in. and drove a Bullock generator by direct connection at 75 r.p.m. Four three-cylinder vertical compound 3000-hp. Westinghouse engines driving 2000-kw. generators were really not exhibits, but a part of the outfit bought by the Exposition.

### Present-Day Prime Movers

At San Francisco, as the exhibits are not furnishing power for any considerable part of the exposition's needs, there was no occasion to install a prime mover of the size that must be taken as representative of this period for large capacity. Such a one, however, is the 35,000-kw. turbo-generator now being completed for the Philadelphia Electric Co. This unit, with its condensing equipment, will occupy a floor space of 1355 sq.ft., which is in marked contrast with the 2376 sq.ft. required for the Centennial engine. The horsepower output of the two units per square foot of area occupied is 34.6 for the new turbo-generator and 0.6 for the Centennial engine. The respective weights are 1,200,000 lb. and 1,400,000 lb., and the speeds 1200 and 36 r.p.m.

### Centennial and Panama-Pacific Machinery Buildings Compared

The machinery buildings of the Centennial and Panama-Pacific expositions furnish a number of striking comparisons and contrasts as shown on the two accompanying pages. These give, by a few illustrations and tabulated data, a comparison of general dimensions and a few important features of these two great buildings. The Centennial Machinery Hall was a larger building, both in length and floor area, than the present Panama-Pacific Palace of Machinery. But this must not be looked upon as a step backward, for at Philadelphia the building de-

Inside the Machinery Palace during the Installation of Exhibits

voted to machinery included everything that could be brought under that general head. In keeping with our present tendency toward specialization, the exhibits at San Francisco have been divided so that printing presses, typewriters, and similar machines now go to the Palace of Liberal Arts, while locomotives and all means of transportation have a building of their own.

One of the striking contrasts between the two buildings is in the materials of construction, for strange as it may seem, more metal was used in the Machinery Hall of Philadelphia 40 years ago than in the present Palace of Machinery in San Francisco. The two pages of illustrations give a hint as to the kind and quantity of these materials.

Another contrast worthy of mention lies in the provisions made for installing exhibits. In Philadelphia there was a total absence of crane service—not a single crane of any kind was used. At San Francisco there are two 30-ton cranes in the middle bay, with one 20-ton crane in each of the two principal side bays. The skids, rollers, and tackle of 1876 have given way to the traveling cranes of 1915.

### General Features of the Present Fair

The grounds are in the city limits of San Francisco and face north on the bay. There are 2¾ miles of buildings, covering an area of 635 acres. While this area is only about half that occupied by the St. Louis Fair (1240 acres) and not even quite as much as the Chicago Fair (733 acres), this is an advantage rather than otherwise, for it means that the tiring distances to be walked are less. It cost more, however, than any exposition to date, for it represents an investment of $58,000,000, whereas the Louisiana Purchase Exposition cost $50,000,000, the Columbian Exposition $20,000,000 and the Centennial Exposition $8,000,000. For the present fair nothing was contributed by the Government as in the cases of the Chicago and St. Louis expositions. The palaces cost more than $12,000,000. Another distinguishing feature of this Fair is that the structures were finished three months before the opening, and it was the first international exposition to be considered completed on time.

White does not predominate in the buildings. The walls are of an ivory tint, and the roofs generally red and flat, with great domes and lofty towers of blue and gold, and green-latticed windows. Add to this the effect of the myriads of flowers, palms and trees, and it is evident that there is here no lack of color.

The tallest feature is the Tower of Jewels, 435 ft. high. On either side of it are the main exhibit palaces, 14 in number. Height in general marks these buildings as compared with the previous fairs, for the walls of the palaces are as high as the average six-story city block. Just east of the group is the amusement section known as "The Zone," to which there has been devoted 65 acres. To the west of the group are the pavilions of the 42 states and 38 foreign countries participating. In addition there are the parade grounds, live-stock pavilion, life-saving stations and the aviation and athletic field.

Eight exhibit palaces subdivided by courts make up the main group, seemingly under one roof and appropriately called "The Walled City." The buildings are in a rectangle, their walls being interconnected and broken only by archways and entrances giving access to the courts between the buildings. The buildings are all of the same height and the architecture generally similar. The courts dividing them north and south are known as the Court of the Universe, the East court, or the Court of Abundance, and the West court, or the Court of the Four Seasons. These eight central palaces are: Mines and Metallurgy, Transportation, Agriculture, Food Products, Varied Industries, Manufactures, Liberal Arts, and Education.

### Palace of Machinery

Flanking this group on the east is the Palace of Machinery, in which centers the most of interest to POWER readers and of whose exhibits more will be told in later issues. It cost approximately $650,000, and is the largest wooden building in the world. It was the first of the exposition palaces to be completed. Ground was broken on New Year's Day, 1913. The architecture is Roman, and the decoration is classic in form, but modern in expression and suggests machinery and invention. Inside, the building, is divided into three north and south aisles, each 101 ft. high and 75 ft. wide, extending the length of the building which is 967 ft. long. On each side of the main structure are side aisles 70 ft. wide covered with shed roofs 41 ft. high to the soffit of the trusses. The total width of the building is 367 ft. and the total floor space 370,000 sq.ft. In other words, it is about three blocks long, 8½ acres in size and as tall as a 13- or 14-story building. Lincoln Beachy, the aviator, flew from one end of it to the other under the roof. This was the first time an aëroplane flight was attempted indoors.

To facilitate the installation of heavy exhibits there are two 30-ton traveling cranes with 5-ton auxiliary hoists in the middle bay and a 20-ton traveling crane in each of the two principal side bays, all operating the length of the building. Railroad tracks enter and cross the building at the center at right angles to the crane travel, so that shipments received by rail can be unloaded from the cars directly by the cranes.

The first machinery exhibit was installed May 27, 1914, nine months before the opening of the Exposition. This was a Busch-Sulzer Diesel engine of 500 hp. The occasion was celebrated with fitting ceremonies attended by exposition, state and city officials and several hundred engineers. The exhibit is to be seen in one of the illustrations herewith.

Wherever possible, the exhibits are to be in operation, and many of them will also embody the exhibition of safety devices being arranged by William Doolittle, safety inspector of the National Metal Trades Association. To increase the convenience of viewing the building's exhibits electric chairs operating on tracks are provided, so that visitors may go from place to place by the pressing of a button and thus may spare themselves the fatigue which is such a drawback to exposition sight-seeing.

The sculptural feature of the Machinery Palace are three figures typifying the Triumvirate of Power, which are repeated in rotation at the tops of the 60-ft. columns flanking the entrances. These are called "Electric Power," "Inventive Power" and "Steam Power" and are the work of Haig Patigian, an Armenian by descent, but a resident of San Francisco. They are 16 ft. high and of a deep-golden color. Electric Power shows a man controlling a lightning bolt with his right hand, and dominating earth under his left foot. Inventive Power is symbolized by a heroic figure wearing the wreath of achievement and holding in his right hand a globe from which rises in flight a winged man. The power of steam is

typified by a man in the act of creating motion with a driving rod of a steam engine attached to a crank which gradually blends with the earth.

### Other Buildings

Flanking the central group upon the west and separated from it by a lagoon, which it partly encircles, is the Palace of Fine Arts. The Palace of Horticulture covers approximately five acres and has as its most prominent feature a steel dome 186 ft. high and 153 ft. diameter, surmounted by a half-sphere 26 ft. high, weighing 26 tons. It is planted with flowers and at night is one of the most spectacular features of the illumination. Festival Hall will be the rendezvous of conventions, among them the Engineering Congress next fall. Nearly all of 350 congresses and conventions will be held here.

Methods of indirect lighting are used for out-of-door effects for the first time at any exposition. The palace walls are flooded by light from high-power arcs, concealed or shaded from the eyes of the spectators by ornamental metal shields or banners. Domes are illuminated from within by powerful searchlights arranged to give varying colored effects. Architectural features are accentuated by the use of "jewels" of polished crystal.

Of the nations which committed themselves to participate before the war, none has withdrawn. They include Argentina, Australia, Austria, Bolivia, Brazil, Canada, Chile, China, Costa Rica, Cuba, Denmark, Dominican Republic, Ecuador, France Guatemala, Haiti, Holland, Honduras, Italy, Japan, Liberia, Mexico, New Zealand, Nicaragua, Norway, Panama, Persia, Peru, Portugal, Salvador, Spain, Sweden, Turkey, Uruguay and Venezuela.

Visiting the Exposition has been facilitated as much as possible by the railroads and local hotels. Rates are being offered on all lines and the hotel men have formed an association, binding themselves to adhere to reasonable prices. In addition numerous boarding houses are available, so that accommodations within the means of all are claimed to be provided in abundance. Still, it is urged by the management that prospective visitors secure their reservations in advance to forestall any chance of disappointment in getting just what they desire.

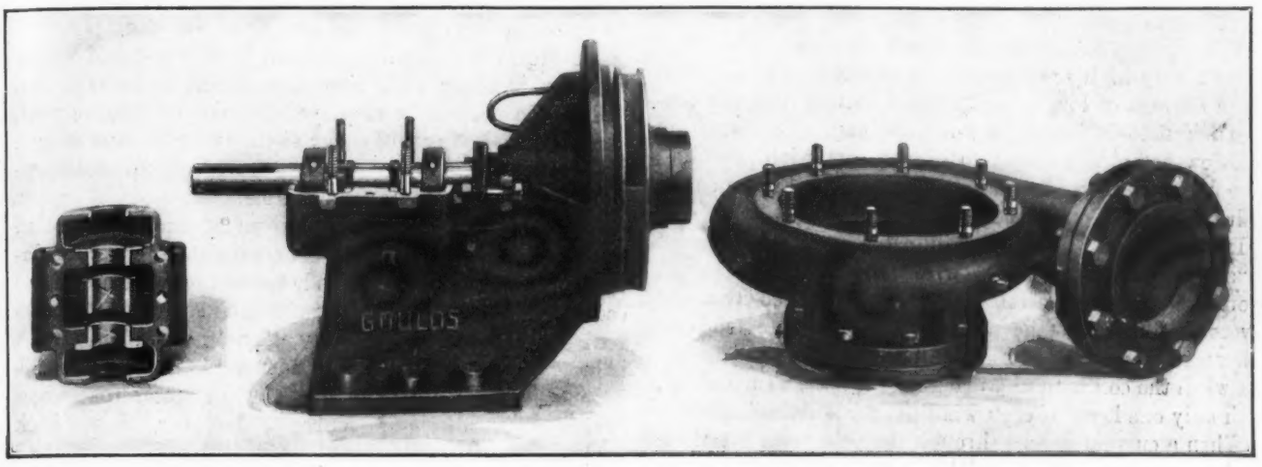
One of the Three Main Portals of the Palace of Machinery

One of the most important features of the Exposition will be the series of congresses, conferences and conventions. As the material exhibits will show world progress on all lines, so will the congresses gather together the experience of the ages in education, science, art, industry and social service.

All in all, the Exposition holds attractions that cannot but make it worth while to any who can find the opportunity, to see it, and this aside from the advantages of viewing the country there and on the way.

## Goulds Single-Stage Centrifugal Pump

The illustration shown herewith is that of the Goulds horizontal single-stage, single-suction, inclosed-impeller centrifugal pump with the casing and bearing cap removed. This pump is designed for directly connecting with electric motors, and is intended to run with different speeds for different capacities and heads.




CENTRIFUGAL PUMP WITH CASING AND BEARING CAP REMOVED

The casing is of the volute type, supported on the bedplate so that it can be swiveled in any one of eight positions. This is a convenient feature where space for pipe fittings is limited, and also allows a discharge elbow to be dispensed with.

The impeller is of the inclosed type and is hydraulically balanced against end thrust. The slight amount of end thrust occurring in operation is taken up by shaft collars bearing upon babbitted surfaces. These collars also serve to space the impeller properly in the casing. The waterway, or volute, is proportioned to convert the energy of the velocity of the water leaving the impeller into pressure, with a minimum of loss due to shock or eddies.

The casting forming the stuffing-box cover of the casing contains two bearings and carries the complete pump when assembled. The outboard end is split horizontally; the bearing cap is held in alignment with the bearing by the taper dowel pins and studs with locknuts. An opening with a hinged lid is provided in the top for inspection of the oil rings. Between the inboard end of the bearing and the face of the stuffing-box there is provided a drip pocket with a drain hole, which catches the necessary drip from the gland and is piped to a sewer.

This pump is manufactured by the Goulds Manufacturing Co., Seneca Falls, N. Y.

# Will Quizz, Jr.

*SYNOPSIS—Will Quizz, Jr., in looking on while a hydrostatic test is applied to a boiler, sees a demonstration of how the spoils system usually works out. Will, however, derives some benefit from his experience by consulting Chief Teller.*

"While away on my vacation, Chief, I found time to peep into some of the boiler rooms in my home town; it has a boiler-inspection law. The inspector is in reality appointed by the mayor and the civil-service part is framed up afterward.

"While the members of the local examining board know nothing about boilers and engines, they are supposed to know how to judge and certify as to the fitness of the candidate after the mayor has appointed him.

"I happened to be chatting with John Starch, who fires at the laundry, when the boiler inspector came in. His method of applying a hydraulic test to the idle boiler puzzled me. The boiler is supposed to be good for 100 lb. and the inspector said he was going to test it for 50 per cent. over-pressure. I watched the gage and he ran the water pressure up to 200 lb., when the shell leaked like a sieve. One of us has this percentage business twisted. What is a 50 per cent. over-pressure, Chief, and how do you figure it? I want to know which of us was wrong."

"I am glad you got some practical information during your vacation, Will, by seeing how other plants are operated. Per cent. means 'by the hundred.' Your problem is easily illustrated by our decimal money: A dollar is 100 cents, and one penny or centum is therefore 1 per cent. A dime is ten one-hundredths, or 10 per cent., and half a dollar is 50 per cent. One hundred represents the base and 50 per cent. added would, of course, be a total of 150.

"You say the boiler is intended for 100 lb. steam pressure, and that it was to be tested to 50 per cent. over-pressure. Fifty per cent. of 100 lb. is 50 lb. Then the total test pressure should be

$$100 + 50 = 150 \text{ lb.}$$

By putting on 200 lb., or doubling the working pressure, the inspector added 100 per cent., incidentally showing an extremely low percentage in his knowledge of percentage."

# Spark-Plug Ignition Systems

By Albert H. Israel

*SYNOPSIS—Explanation of the induction coil and magneto, as well as the operation of the common systems of spark-plug ignition.*

## Simple Induction Coil

The air gap across which is sent the ignition current offers a very high resistance to its passage. For this reason a current of low voltage from a battery or a low-tension magneto is unable to jump the gap. To transform this low-potential current to one of very high potential, amounting to many thousand volts, a device known as the induction coil is employed.

In its simplest form, the induction coil is composed of several layers of coarse wire (the primary) wound around a core of soft-iron wire and surrounded by many layers of fine wire (the secondary). The core tends to concentrate the lines of force and becomes an electromagnet when the coil is in use. In Fig. 1 is shown such a coil, with only one layer of each winding, for simplicity.

When a current is sent through the primary a magnetic field is set up around it, the lines of which pass through the core parallel to the axis, coming out at one end and entering at the other after passing through the layers of the secondary winding. A current is thereby induced in the secondary, the potential of which depends on the relative number of primary and secondary turns. When the current through the primary has reached a constant value, the induced current in the secondary ceases to flow. The magnetic field set up by the primary also tends to retard the current flowing through it, so that it takes longer for the field to build up from zero to maximum than to drop from the maximum to no field when the flow of current ceases. The voltage of the current generated in the secondary winding depends also upon the rapidity with which the intensity of the magnetic field changes. For this reason the current generated in the secondary is of much higher potential when the circuit through the primary is broken than when closed.

No current can be induced or generated in the secondary winding unless the intensity of the magnetic field is either increasing or decreasing. Thus there are two impulses of current in the secondary, one when the primary circuit is closed and the other when it is opened; but, as previously stated, the current induced at the break of the circuit is the only one of sufficient voltage to be utilized.

## Induction Coil with Vibrator

The simple coil just described is used in a system explained later, where the make-and-break occurs once for each explosion and where only one spark is produced. There are systems, however, in which a series of short sparks are produced for each ignition. These add a small mechanism to the simple coil, called a vibrator (see Fig. 2). A current sent through the primary produces a magnetic field, making the core an electromagnet. The tension of the spring tends to keep the two platinum points together, thereby keeping the primary circuit closed; but when the core becomes magnetized it exerts enough force to attract the spring and open the circuit rapidly. As soon as the circuit is opened the core becomes demagnetized and the spring flies back, again closing the circuit. This making and breaking of the circuit by the vibrator occurs at the rate of about one hundred per second, depending on the adjustment. Each time the primary circuit is broken a small current of high potential induced in the secondary jumps the air gap of the spark plug.

As previously stated, a current is also induced in the primary winding each time the circuit is broken, and unless a condenser is employed to take up this current, considerable arcing will occur at the two platinum points, preventing a rapid break of the primary circuit and burning away the points in a short time.

The condenser consists of layers of tinfoil separated from each other by a waxed- or varnished-paper insulation. No connection is made between the two sides of the condenser within itself. The action is such that the current generated in the primary winding when the circuit is broken is absorbed by the condenser, but as soon as this induced current ceases to flow the condenser discharges again. The discharge current, however, flows back through the primary in the opposite direction to that of the battery current, thereby quickly demagnetizing the core. Therefore, the condenser not only does away with the undesirable sparking at the points, but also lessens the

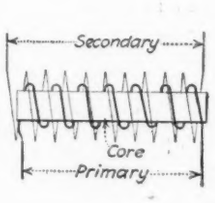



Fig. 1. Simple Induction Coil

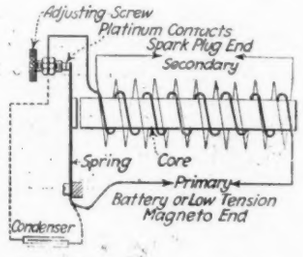



Fig. 2. Coil with Vibrator and Condenser

resistance to the flow of the battery current. It is generally inclosed in the box containing the coil.

Since the secondary current is of very high potential, there would be danger of the insulation being punctured if the circuit through this winding could not be completed. This might happen if a wire had been disconnected from a spark plug, if one of the secondary leads were broken, or if the ground connection became loose or had been left off. Therefore, to prevent the destruction of the coil from these causes, a safety spark gap is inserted in the system of each induction coil and high-tension magneto. The distance between the two points is greater in the safety gap than in the spark plug, hence the current will always jump the gap in the spark plug, except under the conditions mentioned.

## The Magneto

In the induction coil just described the secondary wires remained stationary, while the lines of the electromagnetic field cut them as the intensity of the field was varied. If instead a stationary magnetic field be employed and the wires be moved through it, a similar re-

sult would be obtained. This is the principle employed in the magneto, the essential parts of which are the permanent magnets producing the magnetic field, the pole-pieces through which the magnetic lines of force pass before crossing the path of the armature, and the armature which consists of a core and windings. The core is generally of the shuttle type and the windings depend on the type of magneto; if low tension, the windings consist merely of heavy wire.

The current generated is not constant during one revolution of the armature, but whenever the armature winding passes through the strongest portion of the field, the maximum current is generated; this happens twice during each revolution. To obtain the best spark the maximum current must be utilized, and to do this the mechanism must be constructed so as to make this adjustment possible. The interrupter is generally on the same shaft as the armature, but the distributor arm is on a shaft placed above the armature shaft and is geared to the latter. The armature shaft and distributor shaft are so geared that when the interrupter acts to produce a spark the distributor arm will be in contact with or over one of the segments. To make clear the relation between the speeds of the shafts, assume a four-cylinder four-stroke-cycle engine. Two explosions occur per revolution of the crankshaft and, since two breaks occur at the interrupter points per revolution of the armature shaft, the speed of the two will be the same. There will be four segments, one for each cylinder, to distribute the high-tension current; thus the distributor shaft will make one-half a revolution for each one of the armature shaft.

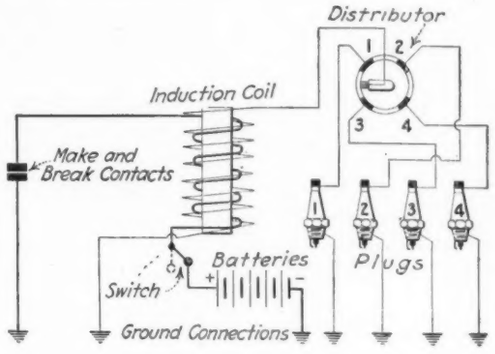



FIG. 3. MAKE-AND-BREAK WITH SIMPLE COIL AND SPARK PLUGS

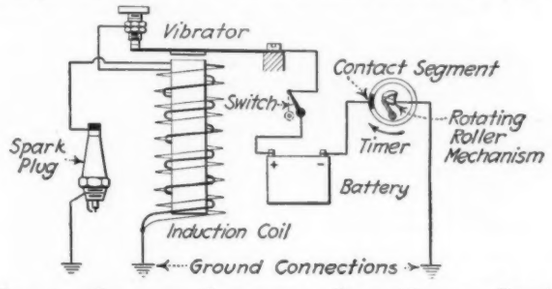



FIG. 4. VIBRATOR INDUCTION COIL (SINGLE COIL)

### DIFFERENCE BETWEEN HIGH-TENSION AND LOW-TENSION MAGNETOS

The chief difference between a low-tension and a high-tension magneto is that the latter is self-contained and very compact, while the former requires a separate induction coil. The high-tension magneto has wound on its armature, in addition to the layers of heavy wire, many layers of light wire which serve as a secondary winding. Instead of using a separate coil the armature serves both as a generator and as an induction coil.

The diagrams showing the different systems have been drawn to show the wiring and not the constructional details; therefore, the interrupter has not been shown on the shaft with the armature. Another thing to note is that the safety spark gap and the condenser have been omitted to prevent confusion.

### SIMPLE COIL (MAKE-AND-BREAK)

When ordinary spark plugs are employed the make-and-break points are outside the cylinder. There are two systems in general use, one in which there is a long make and a second in which there is a very short make. The mechanism is so timed that it is mechanically operated whenever the spark is to occur. The break in the latter system occurs so quickly after the make that the eye cannot detect the two points in contact at all. The fundamental principle of operation is the same, however, in both (see Fig. 3).

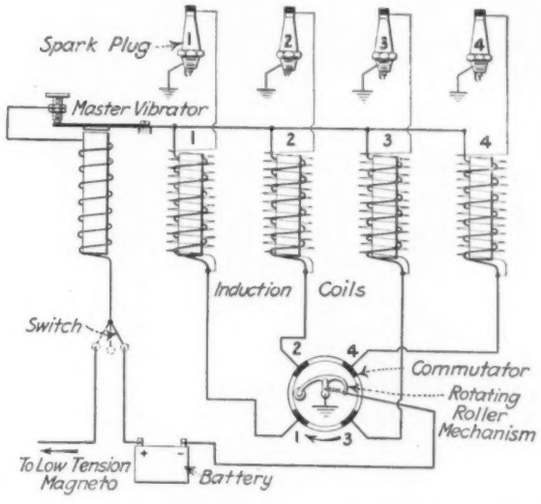



FIG. 5. VIBRATOR INDUCTION COIL (MULTIPLE COIL)

The current passes from the positive terminal of the battery through the primary winding when the points are in contact. This produces a strong magnetic field in the coil, and when it is allowed to shrink suddenly on the opening of the circuit, a current of high voltage is induced in the secondary. The latter flows through the distributor and jumps the gap in the spark plug, completing its circuit by way of the ground.

### VIBRATOR INDUCTION COIL (SINGLE COIL)

In this system, which is shown in Fig. 4, a single induction coil is used. When the timer or commutator closes the primary circuit, which occurs when the roller is in contact with the segment, a current flows from the positive terminal of the battery through the vibrator, the primary winding, the ground and the roller to the negative terminal of the battery, thus completing the circuit. Each time the circuit is broken by the vibrator, a high-tension current is induced in the secondary, which jumps the spark gap of the spark plug. The spark produced at the gap is not merely one, but a series of sparks which succeed each other so rapidly that they appear continuous.

It should, of course, be understood that the roller mechanism of the timer is connected by shafts and gears to the crankshaft, so that there is a definite relation between the speeds of the two, and the spark is made to occur at a definite time.

### Vibrator Induction Coil (Multiple Coil)

The wiring of this system (see Fig. 5) is so arranged that whenever a current passes through any of the induction coils, it must first pass through the master vibrator which is in series with each coil. This saves the use of a number of vibrators and gives a spark of the same intensity in all cylinders. Assume that the roller mechanism is rotating in the direction indicated by the arrow. When it touches segment No. 2, the circuit through the primary is closed, provided that the switch is on. The current then passes from the positive terminal of the battery, through the winding of the master vibrator, coil No. 2, segment 2 and back to the battery, causing the vibrator to act as before explained. Each time the circuit is closed

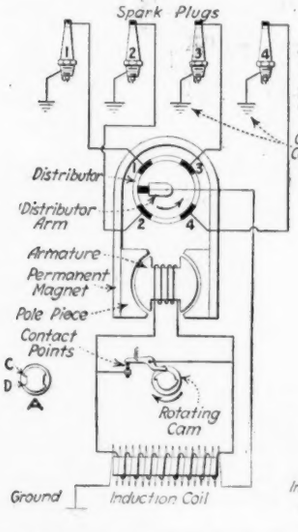



Fig. 6. Low-Tension Magneto

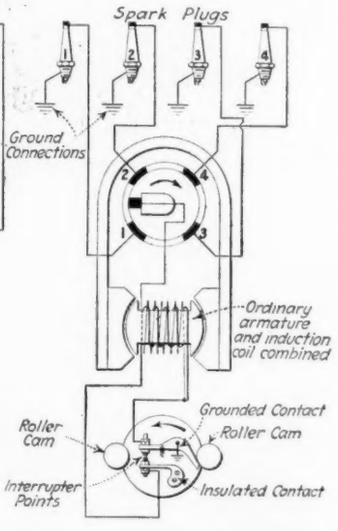



Fig. 7. High-Tension Magneto

and broken by the vibrator a magnetic field appears and disappears in the induction coil No. 2, and sets up a secondary current of high potential, which current jumps the air gap of No. 2 plug. The primary wire from each of the induction coils to the commutator also serves to ground the secondary wire on the respective coils, thereby eliminating four wires. In following out the circuits it should be noted that the roller mechanism is connected to ground.

### Low-Tension Magneto

The system shown in Fig. 6 will operate in either of two ways, depending on the design of the rotating cam which operates the interrupter mechanism. With the cam as shown the system works as follows: The current generated in the armature of the magneto passes through the primary of the induction coil, except when the points of the contact-breaker come together. It is so arranged that the points come together while the maximum current is being generated in the armature. At this instant the major portion of the current passes through the interrupter. The sudden decrease in current flowing through the primary of the coil causes a rapid shrinkage of the field, which, in turn, induces a small current of high voltage in the secondary winding; this passes through the distributor, across the air gap in the plug and through the ground, completing its circuit.

When the cam shown at *A* is used the points of the interrupter are always in contact except during a short period preceding the production of the spark. The current from the armature of the magneto passes through the interrupter until the point *C* of the cam reaches the breaker arm. At this instant the points separate and the whole current is forced to pass through the primary winding of the induction coil. Although this induces a current in the secondary winding, it is not of sufficient potential to jump the spark gap. While the maximum current is being generated in the armature, the point *D* on the cam strikes the breaker arm and the contact points are instantly brought together again. The larger part of the current now flows through the interrupter again and the rapid decrease in the current passing through the primary winding causes a sudden shrinkage of the magnetic field. This induces a current in the secondary of sufficient tension to jump the spark gap.

### High-Tension Magneto

The system shown in Fig. 7 is often called the true high-tension magneto system. The breaker or interrupter mechanism is on the shaft carrying the armature and rotates with it. The roller cams, on the other hand, may rotate on pinions whose positions remain fixed.

In the position shown, the grounded contact arm is about to be pushed inward by the roller cam; thus the interrupter points are about to separate. The armature is short-circuited through the interrupter points except when the spark is to occur. The mechanism is so timed that this takes place when the maximum current is being generated. When a spark is to occur the points are separated and the primary circuit is opened. The current immediately ceases to flow through this winding, causing the field to shrink very rapidly. This, in turn, induces a small current of high potential in the secondary winding on the armature, which passes through the distributor, jumps the spark-plug gap and completes its circuit through the ground.

### Dual System

In this there are two distinct ignition systems which are generally not connected in any way, two sets of spark plugs often being employed. It is a combination of the systems shown in Figs. 5 and 7, namely, the vibrator induction coil and the high-tension magneto.

### Duplex System

This system is the outcome of an improvement on the one shown in Fig. 7. The high-tension magneto is so designed that the armature may be used not only as an induction coil for the current generated in itself, but also for the current from a battery. Thus only the battery is added, but the wiring becomes more complex. An advantage is that without separate induction coils the engine may be started on battery current, which is generally easier than with the current from the magneto. This is due to the fact that the engine must attain considerable speed before the voltage of the current generated in the magneto becomes equal to that of the battery, namely, six to seven volts.

# New Schlotter Blower

By Alfred Gradenwitz

A new type of blower has been brought out by Messrs. Siemens-Schukert Werke, of Berlin, Germany. Like all blowing machines of the screw type, the Schlotter blower, Fig. 1, requires but small floor area, is high-speed and

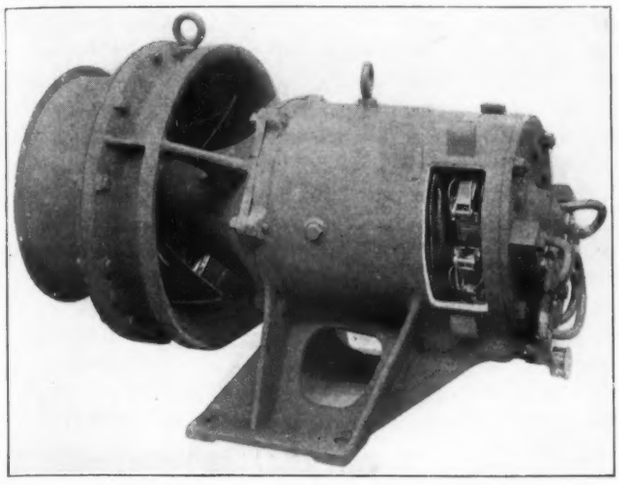


Fig. 1. Schlotter Blower, Motor Driven

Fig. 2. Rotor and Casing

is reversible. Back pressures up to 11.5-in. water column are overcome by a single-stage blower, the maximum efficiency being upward of 80 per cent.

Each blower comprises a 5-vane rotor, Fig. 2, and a guide wheel, Fig. 3, at the outlet. The thrust surfaces of both wheels are of the screw type, that is, surfaces engendered by the rotation of a line and its simultaneous displacement along the axis of rotation. The feature of the guide-wheel principle is that the entrance edges of the guide wheel, so far from coinciding with the outlet edges of the rotor cross them at right angles everywhere. The air current issuing from the rotor is thus subdivided radially by each guide blade and is, at a given air supply, dealt with without a shock.

The curvature of the guide blades, which increases in the direction of rotation of the rotor, results in a con-

Fig. 3. Guide Wheel of Blower

traction of the air current and in a further acceleration of the resting guide wheel, so that a considerable portion of the axial thrust is engendered in the latter. Because of the inertia, the air currents on issuing are slightly rotating and convergent to the axis, so that the minimum cross-section of the jet in the case of a free motion of the air lies at about half the length of the diameter in front of the distributor.

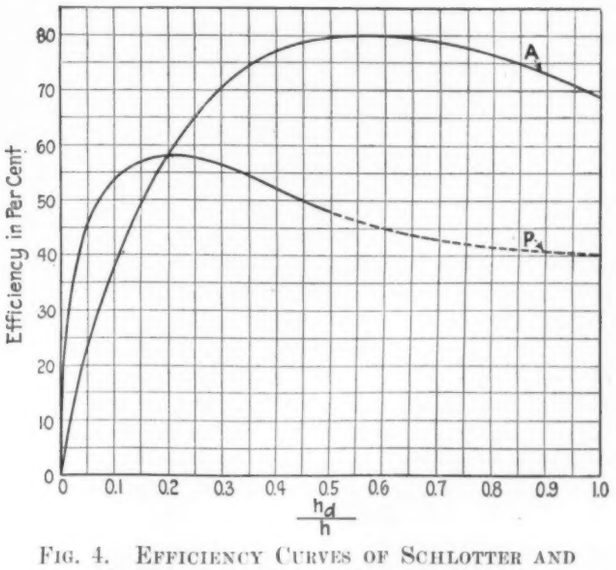



Fig. 4. Efficiency Curves of Schlotter and Centrifugal Fan of Usual Design

The efficiency of a blower depends mainly on the extent to which dynamic pressure in the adjoining tubings can be converted into static pressure. Tests have shown a maximum efficiency of about 80 per cent. to be obtainable in the most favorable case, when connecting the blower to a line of pressure pipes, and 75 per cent. can

be reached with a short outlet tubing corresponding to an increase on cross-section of about 20 per cent., the efficiency decreasing in the case of a diffuser, according to the widening of the latter. These results have been confirmed by tests made on a number of middle-sized blowers, chosen at random, by Professors Brabbee and Kloss, of the Berlin Technical High School, the maximum efficiency found with a pressure pipe connected to the blower being 78 per cent.

An even more important factor than the high maximum efficiency is the fact that the efficiency curve of the Schlotter blower is flat, so that the efficiency remains high over a wide range of loads, from the highest back pressure down to a free escape. In Fig. 4, curve *A* shows the efficiency curve of a Schlotter blower as compared with that of a centrifugal fan of the usual design, as shown in the curve *P*.

Another advantage of the blower is that its power consumption for a given number of revolutions remains constant over practically the whole range of loads. This is valuable in case the back pressure of an installation cannot be predetermined exactly or when working conditions, with a given amount of air, entail variations in back pressure, such as, for instance, with the individual ventilating of mines, when using air pipes of variable lengths.

The annular cast-iron body of the blower is provided with a foot and comprises in its hollow hub the bearings carrying the shaft on the journal of which the rotor and the half coupling (belt pulley) are keyed overhung. Ball bearings are used. Water cooling is provided for the bearings when the blower is used with hot gases.

The standard design is modified in various ways to suit special requirements. The annular body may be fitted with a flange in the place of the foot, in case the blower is to be fixed to a wall. Since every blower is fitted with a thrust bearing to deal with the axial thrust, there is no objection to placing it in a vertical position. When the blower is to work through a conduit, a suction bend is joined to the annular body through which the driving shaft passes.

The rotors are cast either of some light metal (special aluminum alloy) or a high-grade bronze, according to their dimensions and numbers of turns and the gas temperature.

The blower is preferably driven through direct coupling with electric motors, steam, water or air turbines. The most important applications of the blower are for ventilators for boiler and engine rooms; for the individual and main ventilation of mines and tunnels; for air heating, drying and mist-dispelling plants; for forced-draft furnaces and for the removal of dust and shavings.

# Designing Small Transformers

By Norman G. Meade

*SYNOPSIS—Actual calculations in the design of a small transformer such as used for bell circuits or signaling devices.*

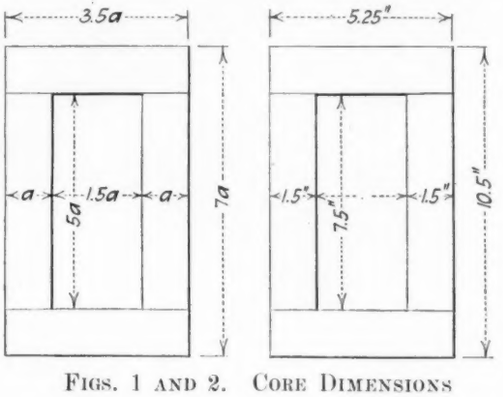
Small transformers with low-voltage secondaries are, to a large extent, replacing batteries for many purposes, such as the operation of electric bells, signaling devices, etc.; and where alternating current is available they are much more satisfactory, as they require no attention. As the secondary voltage is generally below 12 or 15 volts, ordinary bell wiring is sufficiently insulated for the secondary circuits.

The design of the small transformer involves the same calculations as transformers for lighting and power purposes. It is necessary to know or assume several quantities, such as the useful secondary output in kilowatts, the primary voltage, secondary voltage, and the frequency of the system on which the transformer is to operate. Let it be desired to design a transformer to operate from a 110-volt, 60-cycle circuit, which will have a secondary voltage of 10 and a secondary current of 10 amp.

$$Efficiency = \frac{watts\ output}{watts\ input}$$

For an output of 100 watts, assuming an efficiency of 85 per cent.,* the input would be $100 \div 0.85 = 118$ watts. Therefore, the total estimated losses are not to exceed 18 watts. These losses are made up of three components—hysteresis, eddy currents and copper losses. The copper or $I^2R$ loss and the core loss (hysteresis and eddy currents) should be about equal. For intermittent service the copper loss can be somewhat the larger of the two; hence it will be taken as 10 watts and the core loss 8 watts.

Assume the density of the sheet-iron core to be 30,000 lines of force per square inch. For annealed sheet iron at this density, the hysteresis loss is 0.15 watt per cubic inch. The eddy-current loss should be small on account of the laminated core; therefore assume it to be 2 watts and the hysteresis loss 6 watts. The volume of the iron in the core will then be




Figs. 1 and 2. Core Dimensions

$$\frac{6}{0.15} = 40\ cu.in.$$

The core must be proportionate with regard to the winding space and the length of the magnetic circuit. Let *a* represent the width of the core, as in Fig. 1, 7*a* the height of the core, 3.5*a* the total width, 1.5*a* the horizon-

*This efficiency is somewhat lower than would be obtained in a well designed transformer of this size under full load.—EDITOR.

tal inside distance between legs, and $5a$ the distance between the yokes. The cross-section of the core is $a^2$. Then the volume of the core is

$$V = (2 \times 3.5a + 2 \times 5a)a^2$$

or

$$V = 17a^3 = 40 \text{ cu.in.}$$

Whence, $a = \sqrt[3]{\frac{40}{17}} = 1.34$, approximately.

Let $a$ be 1.5, on account of some loss of space due to laminations. Then the core dimensions will be as shown in Fig. 2 and the available winding space will be 2.25 in. between cores and 7.5 in. between yokes. Let the length of coil be 7 in. The secondary will be wound next to the cores so as to reduce the length of the heavier wire, and the primary will be wound over the secondary. The secondary current at full load will be 10 amp., and, as the primary and the secondary coils are wound in two sections, the secondary voltage for each coil will be 5 volts, but the conductor will carry 10 amp. Allow 1000 circ.mils per ampere. Then the size of the secondary conductor will be $10 \times 1000 = 10{,}000$ circ.mils, which corresponds nearest to a No. 10 wire.

The primary watts at full load are 118; hence the primary current will be

$$\frac{\textit{Primary watts}}{\textit{Primary voltage}} = \frac{118}{110} = 1.07 \textit{ amp.}$$

The power factor can be neglected and, as the magnetizing current is small, the primary current will be taken at 1.25 amp. The size of the primary wire will then be

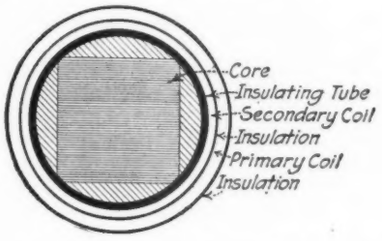



FIG. 3. SECTION THROUGH CORE AND COIL

$1.25 \times 1000 = 1250$ circ.mils, which corresponds nearly with a No. 19 wire.

The relation between the maximum flux and the effective primary voltage is as follows:

$$V_p = \frac{4.44\, N \times T_p \times n}{10^8}$$

where,

$V_p$ = Primary voltage;
$N$ = Maximum magnetic flux;
$T_p$ = Primary turns;
$n$ = Frequency.

The maximum magnetic flux equals the flux density, in the present case 30,000 lines per square inch, times the cross-section of the core in square inches; that is,

$$N = 30{,}000 \times 2.25 = 67{,}500 \textit{ lines.}$$

Substituting in the above formula,

$$110 = \frac{4.44 \times 67{,}500 \times T_p \times 60}{10^8}, \text{ and}$$

$$T_p = \frac{110 \times 10^8}{4.44 \times 67{,}500 \times 60} = 611 \text{ (approximately)}$$

To arrive at even numbers make the total primary turns 612, or 306 turns on each core. The number of secondary turns will be

$$\frac{\textit{Secondary voltage}}{\textit{Primary voltage}} \times T_p = \frac{10}{110} \times 612 = 56$$

or 28 turns to the coil. The arrangement of the windings on the core is shown in Fig. 3. The corners of the core are slightly rounded and it has four segmental blocks of hardwood on four sides. The wood should be well filled with shellac or insulating paint. The inside diameter $d$ of the secondary coil figures 2.12 in., as illustrated in Fig. 4; but as the corners of the core are rounded, the inside diameter will be taken as 2 in.

From a magnet wire table it will be found that No. 10 wire has 8.54 turns to the inch and, as the length of the coils is 7 in., there is twice the space needed for the secondary winding of 28 turns per coil. Therefore, it will be

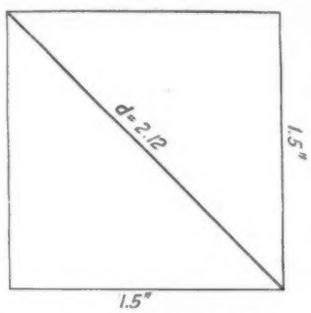



FIG. 4. ILLUSTRATING METHOD OF DETERMINING INSIDE DIAMETER OF SECONDARY COIL

necessary to wind a cord the diameter of the wire parallel with it, to make a good job. The secondary winding should be wound on a stiff insulating tube of the required diameter; a piece of mailing tube will do. Before winding, the tube should be thoroughly impregnated with insulating compound. For winding, the tube should be slipped on a wooden arbor and placed in a lathe. When the winding is in place the ends should be secured with cord and wrapped with two or three thicknesses of oiled cloth, then wrapped with webbing and painted or shellacked. The ends of the winding should be cut off about an inch from the core and flexible cord for the leads soldered on and the joints taped.

Each primary coil consists of 306 turns of No. 19 wire; there are 22.77 turns to the inch and $22.77 \times 7 = 159.39$ turns to the length of the coil, which will make about two layers for the primary coils. Flexible leads are soldered to the primary winding and the whole is bound lengthwise, that is, inside and out, with webbing and thoroughly painted. The coil should now be wrapped with oiled cloth.

In building up the cores the sheets of iron should be cut in different lengths. For example, referring to Fig. 2, cut half the sheets 7½ in. long and half 10.5 in. and assemble them with alternate strips, long and short; then securely rivet the bundle. The yokes should be assembled in like manner, which will allow the ends of the yokes and those of the cores to mortise. One yoke and two cores can be assembled and riveted, the coil slipped on and the second keeper placed in position and riveted. The coils should be so connected that the current flows in opposite directions in the two legs.

The $I^2R$ loss should be checked after calculations are made and if too great, should be decreased by increasing the size of the wire. This is a cut-and-try method to secure the proper size of wire.

## Just for Fun

[In the issue of Jan. 19 we asked for accounts of stupidity in a class with those printed in the same issue under the heading, "Some Original Ideas." Following are a few of the best stories which have been received.—EDITOR.]

The following method of laying up three 18-ft. by 72-in. return-tubular boilers was at least unusual. After pouring 18 gal. of cylinder oil through the top manhole, the boilers were filled and then slowly drained. The man in charge expressed an opinion that the boilers would be protected from rust indefinitely; in which I presume he was correct. The removal of the oil, however, upon resuming operations will call for another original idea.—*Ernest A. Tichenor, South Connellsville, Penn.*

A student taking an examination in steam engineering was asked what a "self-supporting stack" was. He answered that it was one which paid the interest on the investment by using natural instead of fan draft.

A turbine test man was sent to the stockroom for putty and came back lugging a 50-lb. keg of white lead and asked for some dry putty, as the new stuff was too soft. [This last joke looks "putty" thin to us.—EDITOR.]—*R. Blumenfeld, Brooklyn, N. Y.*

In a small town a short distance from New York City a town meeting was called to consider alterations to the steam-heating system in the high-school building, as it was not working properly. A member of the school board made a report, with recommendations, which was severely criticized by one of the Board of Aldermen, who made the following statement:

"The heating plant was not installed correctly in the first place, for the boiler is in the wrong end of the building, as it is now in the south end and should have been placed in the north end, because steam in pipes will flow better from north to south than from south to north."

The above statement was actually made in public, and if desired, I will furnish proof of its authenticity.—*W. A. Armes, Norwood, Mass.*

During the recent cold spell I noticed a large bulged place on the brass plunger of a deep-well pump temporarily out of use for repairs, which resembled a snake after swallowing a large toad. On examining the piston it was found to be burst a distance of five inches, due to water leaking past the threads on the rod and freezing solid. On the same repair job it was necessary to take down a part of the discharge line which contained a three-inch gate valve. On removing the valve it was turned around several times. Anyone would have thought all the water had been spilled out, but such was not the case, and the result was a burst valve, but it was not noticed and was put back in the line.

When all was apparently ready the valve outside was opened to the tank pressure, and a large spray of water issued from the ruptured valve, of which a bystander and myself soaked up a good supply. The young man thought it was from over-pressure, and explained it to the fireman by saying that he saw it open up like a clam shell.—*W. H. Corbin, Sharples, W. Va.*

## Bayer Quick-Acting Monkey-Wrench

A quick-acting and convenient monkey-wrench differing from the usual design has been placed on the market by the Bayer Steam Soot Blower Co., of St. Louis. The ordinary thumb-nut is replaced by a sliding collar which may be moved up and down the handle to operate the jaw. The motion of the collar is transmitted to the screw of the wrench by means of a pin attached to the collar and fitting into a spiral groove in the screw rod. Moving the collar toward the outer end of the handle closes the jaws and *vice versa*. When the collar is up against the movable jaw the wrench is wide open. In this position the

BAYER QUICK-ACTING MONKEY-WRENCH

wrench may be slipped over a nut. A pull on the collar will adjust the jaws, and pressure to do the turning may be applied at the same instant.

Including the cap at the end of the handle, the wrench is made up of five pieces: The handle and stationary jaw, the movable jaw, the collar, screw rod and cap. The handle is a solid steel forging of elliptical shape with a recess for the screw rod. The latter is thus protected so that there is little opportunity for bending it or getting it out of alignment. The collar is easy to move, and altogether, the wrench is a most convenient tool.

**Heat Value Calculation**—The combustion of a given element always results in the generation of a fixed amount of heat. Thus, when a pound of pure carbon burns completely (forming $CO_2$), 14,600 B.t.u. is produced. Consequently, the heat value of carbon is said to be 14,600 B.t.u. per lb., which is the unit of weight almost universally used in this country. When a pound of pure carbon burns incompletely (forming CO), only 4450 B.t.u. is produced. But if, in turn, the resulting $2\frac{3}{3}$ lb. of CO, which is a combustible gas, is burned, 10,150 additional B.t.u. is liberated, making the total heat produced equal to 14,600 B.t.u., just the same as though the pound of carbon had burned completely (to $CO_2$) in the first place. Hence, the heat value of CO is

$$\frac{10{,}150}{2.333} = 4350 \text{ B.t.u. per lb.}$$

The heat values for carbon and hydrogen were established by experiment and hence probably are not absolutely exact. In fact, some authorities give values for carbon as low as 14,220 and as high as 14,647, and for hydrogen as low as 61,816 and as high as 62,032, but 14,600 and 62,000 are the most widely accepted and used.

# Step-Bearing Accumulator for a Vertical Turbine

By W. R. Bankhead

In the power plant at the Puget Sound navy yard there is a 500-kw. vertical turbine, the step bearing of which is supplied with oil by two duplex pumps capable of delivering oil at 800 lb. per sq.in. The oil passes through a baffle before reaching the bearing, which reduces it to a pressure sufficient to support the weight of the moving parts. This pressure varies from 155 lb. at no load to 190 at full load. These pumps also supply oil to the other bearings of the turbine and to a tank for a gravity system.

The step bearing has been burned out several times on account of the failure of the oil pressure. The pumps originally had no governor nor air chamber to steady the pressure. A failure for one second would cause the bearing to begin to cut, and the machine had to be shut down for repairs.

An accumulator of some kind was needed, and as the space was limited it was decided to install a vertical steel tube, into the bottom of which the oil should be pumped, compressing the air in the top of the tube, which acts as a spring to force the oil out to the step bearing in case the oil pump failed. This form of accumulator is cheaper to build than a weighted-piston type, costing only about one-half as much.

The tube is 11 ft. long, 12 in. inside diameter, and ½ in. thick, and is made of seamless rolled steel. In each end of the tube ¾-in. steel heads were welded by the oxy-acetylene process, and when tested to 2000 lb. hydrostatic pressure it was found to be tight; this is necessary to make such an accumulator successful. There is a check valve between the pumps and the accumulator and a gage

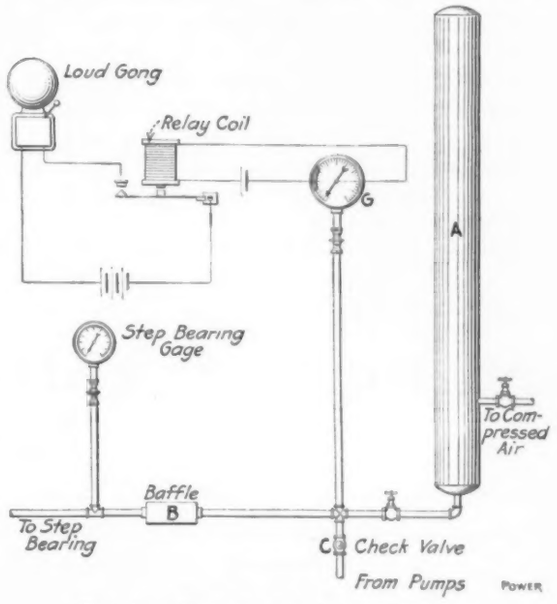



Fig. 2. Details of Alarm System

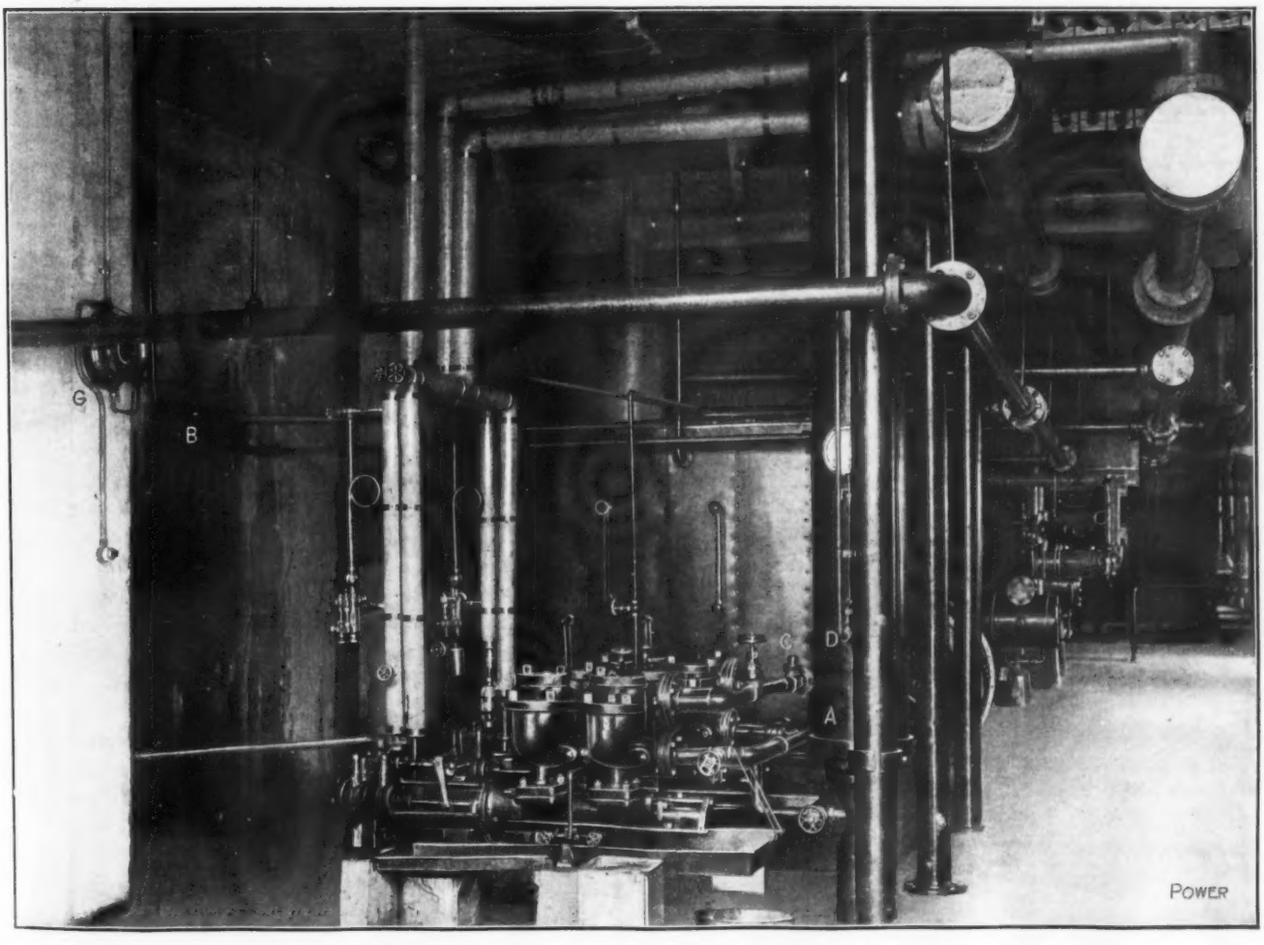



Fig. 1. Vertical Accumulator A in Limited Space near Oil Pumps

between the accumulator and the baffle. The gage is so fitted that when the oil pressure falls below 600 lb., a gong which can be heard all over the engine room announces the drop in pressure.

Fig. 1 shows the location of the accumulator *A*. The baffle *B* is at the base of the turbine foundation, and *C* is the check valve between the pumps and the accumulator. *D* is the connection to the compressed air. The high-pressure oil gage which closes the electric circuit is shown at *G*. The accumulator was first filled with compressed air at 100 lb. to insure a good supply and to reduce the quantity of oil necessary. Fig. 2 shows the details of the alarm system.

The primary purpose of this accumulator was to guard against a sudden failure and to give the operator warning in time to start another pump or to shut down the turbine. For 12 min. after the pump is stopped the accumulator will maintain a pressure sufficient to support the step bearing with the forced lubrication system still on, and for 23 min. to the step bearing only.

In practice it has proved better than was expected, as it keeps steady pressure and acts as a governor for the pumps, which can be run on a wide-open throttle.

The turbine has been running almost continually for eight months day and night without any step-bearing trouble whatever.

Instead of being an uncertain and unreliable machine, the accumulator has made this turbine one of the most dependable in the plant, and we have been able to "forget" the step bearing.

# Setting the Valves of a Four-Valve Engine

By H. Wiegand

*SYNOPSIS—Tells in a simple and thorough way how to set the valves of a four-valve engine to run either over or under.*

In setting the valves of a four-valve engine the usual method of placing the engine on the center is used. A tram may be used to facilitate marking the different positions of the crosshead, crank, etc.

Turn the engine, which is supposed to run over, until the crosshead is at the point of the crank end release *R*, Fig. 1, which shows the positions of the crosshead, crank, throw of eccentric and rocker-arm in diagram form. As the crank-end exhaust valve must be line to line with the port to open and, when the crosshead is at *C*, begin to close for compression, it is evident that the rocker-arms must be in the same place at these two points of crosshead or crank position.

Therefore, it is not necessary to connect the valves until the right position of the eccentric has been found. Set the throw of the eccentric near the angle of advance point *B*, and mark the position of the rocker-arm line by a line across the pin and hub or hub and pin-boss; then fasten the eccentric with the setscrew or a false key and turn the engine over to the crank-end compression point

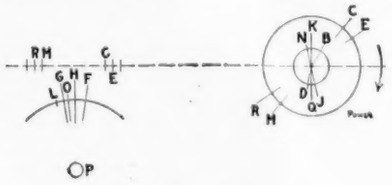



Fig. 1.

*C*. The throw of the eccentric will now be at *D* and the rocker-arm, instead of returning to *F*, will go beyond it to *G*. The eccentric must therefore be turned back until the rocker-arm reaches point *H*, central between *F* and *G*.

To accurately locate *H*, divide the distance between the marks on the hub and pin or pin-boss. The throw of the eccentric is now at *J* and the rocker-arm at *H*, with the crank and crosshead at *C*. Turned over to *R*, the throw of the eccentric will be at *K* and the rocker-arm will have moved to *L* and back to *H*. The crank-end exhaust valve can now be set line to line and the rods and valve lever put in the desired position. The latter may be fastened with a false key and a line drawn across the face of the lever and the valve stem to mark the position

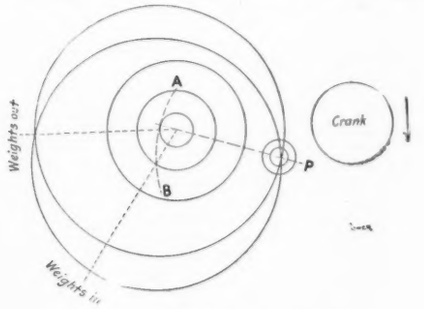



Fig. 2.

of the valve. The crank must now be turned back to *M*, the point of head-end compression, and the head-end exhaust valve connected and set line to line with the port. The eccentric will now be at *N*, the rocker-arm at *O*. Turned over to *E* or head-end release, the throw of the eccentric will be at *Q*, the rocker-arm at *O*, the crosshead at *E*, and the valve will begin to open for release. The eccentric and valve levers can now be marked for keyseating and the rods locked and marked for length. To set the admission valves, place the governor in its midway position and turn it so that with the weights "in," the throw of its eccentric is in line with that of the exhaust eccentric; then fasten it there. Next turn the shaft to its crank-end center and throw the weights of the governor out. With the valve-gear rods set at their proper lengths, set the crank-end admission valve line to line with the port and fasten the lever to the stem.

Now throw the weights in and note how far the valve has opened. The designer will give the lead and the lap of the valve at dead-centers. Suppose this valve should have ¼-in. lead and $\frac{1}{32}$-in. lap, it must move $\frac{9}{32}$ in. by throwing the weights out or in. If it does not move enough the governor must be advanced, or set back if the

valve moves too much. The two large circles, Fig. 2, represent the greatest and the least travel of the eccentric. The diameters of the two smallest circles, Fig. 2, represent the greatest and least travels of the valves, the next larger one the bore of the wheel and the two large circles the positions of the eccentric with governor weights in and out. The arc $AB$ drawn from the center of the pivot pin $P$ marks the path of the center of the eccentric and

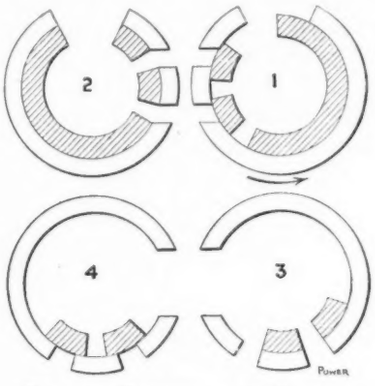



FIG. 3. POSITIONS OF VALVES

the two dotted lines drawn from the center of the wheel mark the throw of the eccentric at its greatest and at its least travel. It will be seen that the position of the governor is given by the distance between the two eccentric circles or the amount of valve motion at dead centers; also that the throw of the eccentric at least travel is opposite the crank and that it is impossible for the valves to open if they have lap at dead-center, while the governor weights are out. After finding the correct governor position the crank-end valve may be set to its proper lap and the engine turned over to the head-end center for setting the head-end valves in the same way.

Turn the engine over one revolution with the weights out to make sure that the admission valves do not open, then turn it one revolution with the weights in to note the point of admission to the point of cutoff and to see that no negative lap occurs from overtravel, which would happen

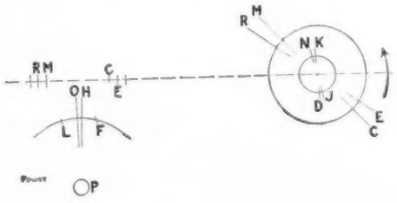



FIG. 4.

if the valve in Fig. 3 were turned further in the direction of the arrow. By decreasing the governor travel the negative lap may be reduced if it is not over $\frac{1}{16}$ in.; if more, a new valve is usually required. The governor, valve levers and rods can now be marked as described.

To reverse this engine set the exhaust valves by turning the shaft to $R$, Fig. 4, the point of crank-end release, when the engine is running under. Then turn the eccentric in the running-over direction until the crank-end exhaust valve is line to line with the port. The throw of the eccentric will be at $J$, the rocker-arm at $H$ and, turned over to $C$, the throw will be at $K$, with the valve again closing for compression. The head-end exhaust valve will be line to line at $E$ and $C$.

The weight-arms of the governor and the springs and links require changing to throw the eccentric the other way. The key has to be taken out and the governor turned in the direction of running "under" until, with the engine on its crank-center and the governor weights "in," the

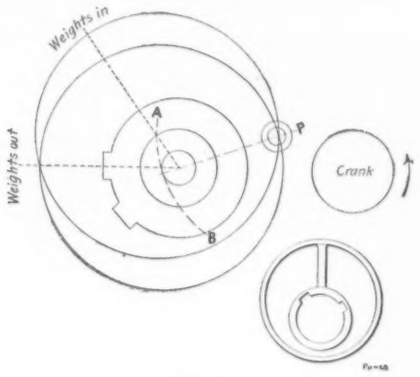



FIG. 5.

crank-end admission valve has ¼-in. lead. Fasten the governor and turn the engine under to the head center and the head-end valve will show the same lead. Now throw the weights out and examine the lap; if it is not quite right the governor may have to be moved a little either way. The engine is reversed and the new keyways may be marked.

Fig. 5 shows the position of the eccentric for running under and also the keyways for running the engine in both directions.

## Wrong Voltage on Motor

BY J. A. HORTON

An operator complained that his induction motor was overheating and stated that it was free from grounds; that the trouble was in the motor itself because the one that it had replaced operated normally up to the time of its replacement; and that his service voltage was 550 to 600. He added that one phase took hardly any current, while the two other phases did all of the work.

As the replaced motor had operated normally, the unbalanced symptom suggested a reversed internal connection. Accordingly, a winder was sent to inspect the end connections and to change them if necessary. No changes were needed because the connections were all right. Just after trying the motor and before the oil switch had been opened, the winder approached the connections with the intention of taping some bare ones. The operator hastily opened the oil switch and warned him that the line voltage was 550 volts and that one leg was grounded through a fault. The winder was no general trouble man, but he had looked at the nameplate of the motor and, as he had seen 440 volts marked on it, he failed to see any good reason why a 440-volt motor should be operated on a 550-volt circuit. Wrong voltage was the only trouble.

As far as the unbalancing of the phases was concerned, what had seemed to be an unbalanced condition was due to the fact that the operator, in using a single ammeter on a three-phase circuit, failed to note that the current had changed while changing his meter from one leg of the circuit to the other. The three legs had not been read under like conditions of the load.

# A. S. M. E. Boiler Code Approved by Council

Something of an event in the history of the American Society of Mechanical Engineers occurred Saturday, Feb. 13, when the council approved the proposed Boiler Code finally submitted by the committee appointed for that purpose. Probably no one appreciated what an important undertaking this would prove when the suggestion was first made that the society draft standard specifications for the construction, equipment and use of steam boilers with the hope that they might be made the basis of uniform legislation in the several states. Certainly no one anticipated the monumental task it would develop into, nor the keenness of the interest that would be enlisted from so many quarters, many of them unexpected. One member of the council in moving a vote of thanks to the committee characterized the code as the greatest single piece of work that the society has ever done.

In spite of the opposition that was manifested, especially in the early part of the committee's work, by the various industries which feared the code would tend to injure their business and were jealous lest others might obtain advantages over them in one way or another, all of these conflicting interests were finally reconciled; the council approved the code unanimously and even from outside of the society there is practically no objection to the code in its final form.

It is reported that immediately it became possible to secure a copy of the code in its approved form, one was rushed to Indianapolis to be embodied in a bill to be presented, and it is believed that the State of Indiana will adopt the code entirely in the very near future and that eight to a dozen other states are all ready to follow suit before many months have passed by. The council voted not to discharge the committee, but to continue it indefinitely with the idea that it may be made a permanent committee by action of the society, with power to revise the code from time to time whenever that may be warranted due to advances in the arts. This committee was augmented to include not only the original members, but the later advisory committee of eighteen members.

While the existence of the committee dates back to Sept. 15, 1911, when it was appointed during the presidency of the late Col. E. D. Meier, "to formulate standard specifications for the construction of steam boilers and other pressure vessels and for the care of same in service," most of its real activity has been shown during the past year.

The council's instructions were to formulate a model engineers' and firemen's license law, a model boiler-inspection law and a standard code of boiler rules. The necessity of properly constructing, installing and inspecting boilers was naturally to receive consideration and the make-up of the committee was appropriately chosen. The accompanying portraits show the original members.

The chairman, John A. Stevens, at the age of 27 was granted an unlimited engineer's license for ocean steamship—highest class. He resigned as first assistant engineer of U. S. M. S. "St. Paul" in 1893 to take the position of chief engineer of the Merrimac Manufacturing Co. in Lowell, Mass. For eleven years he made all power-plant layouts and estimates for this company. In 1907 he was appointed by the Governor a member of the Massachusetts Board of Boiler Rules and served two terms of three years each, during the first of which the Massachusetts rules were formulated, which have since been the pattern of so many other states. Since 1909 he has practiced consulting engineering.

The other members of the committee included two professors of engineering, two boiler manufacturers, a steel-plate manufacturer and an insurance engineer.

Prof. R. C. Carpenter is professor of experimental engineering at Sibley College, Cornell University, Ithaca, N. Y., a consulting engineer with extensive practice and experience in the boiler field, the author of "Experimental Engineering" and other engineering books, and is frequently called as an expert witness in legal cases concerning boilers.

Prof. Edward F. Miller is professor of steam engineering at the Massachusetts Institute of Technology, Boston, Mass., and similarly qualified by experience. His special services on the committee were in connection with the safety-valve specifications and mathematical formulas.

Col. E. D. Meier, since deceased, was the president and chief engineer of the Heine Safety Boiler Co., St. Louis, Mo., and a builder of water-tube boilers.

Richard Hammond, president of the Lake Erie Engineering Works, Buffalo, N. Y., brought the experience of a maker of marine and tubular boilers to the committee. His advice was especially helpful in relation to rules concerning large-diameter boilers and stayed surfaces.

Dr. Charles L. Huston, vice-president and works manager of the Lukens Iron & Steel Co., and also of the Jacobs-Shupert U. S. Fire Box Co., was particularly valuable to the committee as its special metallurgical expert, for he is one of the foremost investigators into the scientific manufacture of iron and steel plate.

Finally, as the representative of the field of boiler inspection and insurance, William H. Boehm, superintendent of the departments of steam boiler and flywheel insurance of the Fidelity & Casualty Co., New York, rounded out appropriately the committee's personnel.

A first preliminary draft of the rules proposed after consideration had been given to the rules then in force in such states as had any, was prepared and distributed among authorities qualified to criticise it and make suggestions at the St. Paul meeting of the society in May of last year. The interest aroused prompted the arrangement for a public hearing in New York in the fall. This took place in September and another in October, after which the code was revised and a third printing made of the preliminary draft. The fourth printing was called a Progress Report and brought formally before the annual meeting in New York last December. The unusually extended discussion which ensued has already been referred to. Shortly thereafter there was a conference with the boiler manufacturers' association at which it was decided to revise the code at once while the suggestions were fresh in mind and submit the details to representatives of all organizations and interests who would be affected by the proposed code. The result was the appointment of the following advisory committee:

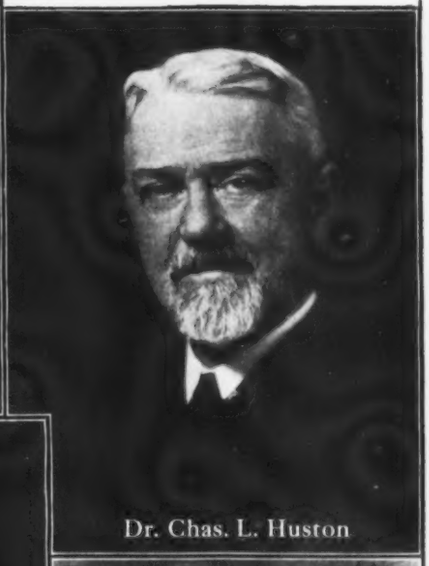
# A.S.M.E. Committee on Uniform Boiler Specifications

**American industries can now afford a little better boiler for a little more money, and a little more regard for human life.**

Wm. H. Boehm

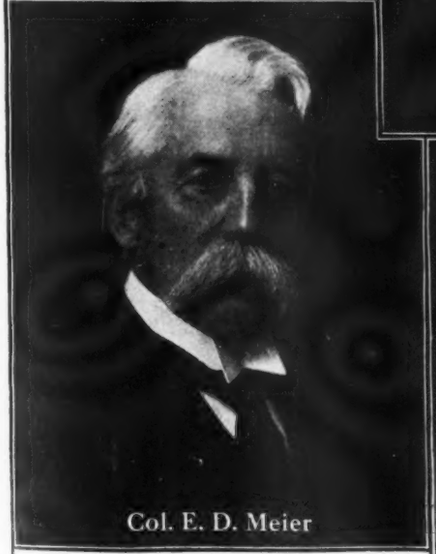
**The United States has less legislation regarding boilers than any other civilized country—and more explosions.**

Prof. R. C. Carpenter

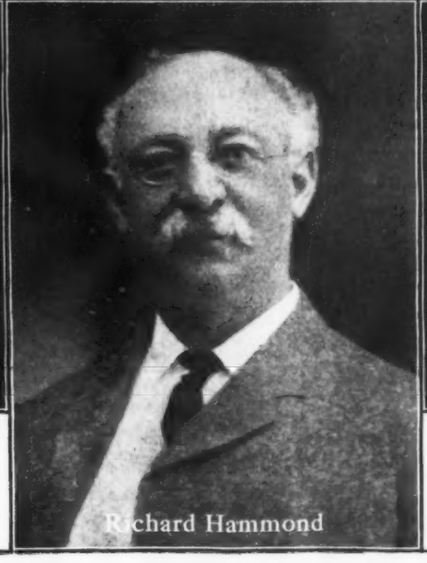


Dr. Chas. L. Huston

John A. Stevens



Col. E. D. Meier



Richard Hammond

Prof. Edwd. F. Miller

**An ignorant or careless attendant can explode the best boiler ever built, and the better the boiler, the more disastrous the explosion.**

**The report of this committee embodies the collective wisdom of the world's best experts.**

D. S. Jacobus, advisory engineer, Babcock & Wilcox Co., New York.
F. H. Clark, general superintendent of motive power, Baltimore & Ohio R.R., Baltimore, Md.
H. H. Vaughan, assistant to vice-president, Canadian Pacific Ry., Montreal, Canada.
A. L. Humphrey, vice-president and general manager, Westinghouse Air Brake Co., Wilmerding, Penn.
Karl Ferrari, Erie City Iron Works, Erie, Penn.
H. G. Stott, superintendent of motive power, Interborough Rapid Transit Co., New York.
I. E. Moultrop, assistant superintendent construction bureau, Edison Electric Illuminating Co. of Boston, Mass.
W. F. MacGregor, superintendent of experimental department, J. I. Case Threshing Machine Co., Racine, Wis.
Richard D. Reed, H. B. Smith & Co., Westfield, Mass.
M. F. Moore, assistant to president, Kewanee Boiler Co., Kewanee, Ill.
S. F. Jeter, supervising inspector, Hartford Steam Boiler Inspection & Insurance Co., Hartford, Conn.
Thomas E. Durban, general manager, Erie City Iron Works, Erie, Penn.
F. W. Dean, consulting engineer, Boston, Mass.
William F. Kiesel, assistant mechanical engineer, Pennsylvania R.R., Altoona, Penn.
Arthur M. Greene, Jr., professor of mechanical engineering, Rensselaer Polytechnic Institute, Troy, N. Y.
Charles E. Gorton, Gorton & Lidgerwood Co., New York.
Elbert C. Fisher, vice-president and general manager, Wickes Boiler Co., Saginaw, Mich.
C. W. Obert, associate editor, American Society Mechanical Engineers, and secretary to the Boiler Code Committee, New York.

The work of revision has continued without interruption, since December 15, except for Sundays and holidays including both day and night sessions. After so tedious a grind it is naturally very gratifying to the hard-worked committee that its efforts have been successful and the report received by the council. For its part the council and all the members of the society, and engineers and others outside of the society too, for that matter, should and do feel their obligation for the earnest work of the men engaged on it. Is it too much to say that humanity generally should honor these men, for their efforts are certain to result in decreased loss of life and property from boiler accidents?

## New Blackburn-Smith Twin Filter

A new type of Blackburn-Smith feed-water filter and grease extractor, having twin bodies controlled by a single set of inlet and outlet valves, is built by James Beggs & Co., 38 Warren St., New York City.

A plant carrying a varying load, or one which operates twenty-four hours per day, requires a filter having considerable flexibility as to capacity, and one which would permit of the cleaning of one part while the other was in operation. If such a filter were of such size that either side alone could carry the regular load, then the two sides could be thrown in during the peak load, and so filter the water at all times without interference by the necessary cleanings. This filter, Fig. 1, is designed to meet such conditions.

The turning of both valves to one limit bypasses the corresponding body, and the other body is bypassed by turning both valves to the other limit, thus permitting the alternate operation and cleaning of either side. The combined operation of both sides, as would be desirable during the peak load, is accomplished by turning the valves to mid-position.

The filter is made up of a number of parts, so that breakage or disarrangement of any particular section does not necessitate the discontinuance of all filter service. The valves are of the double-seat type and the disk working between the seats is self-seating, which prevent leakage due to dirt deposited on either disk or seat.

The filter chests are the same as in the single type of filter, each divided into an inlet and an outlet chamber

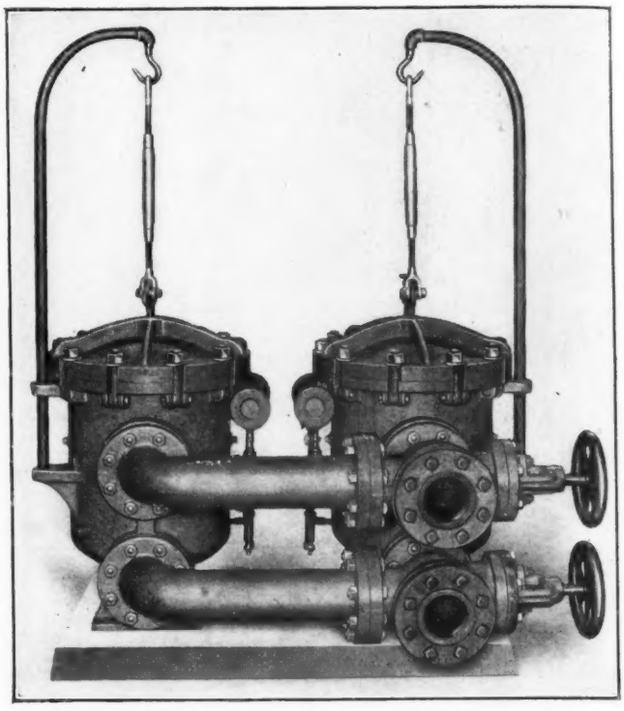


FIG. 1. NEW TWIN FILTER

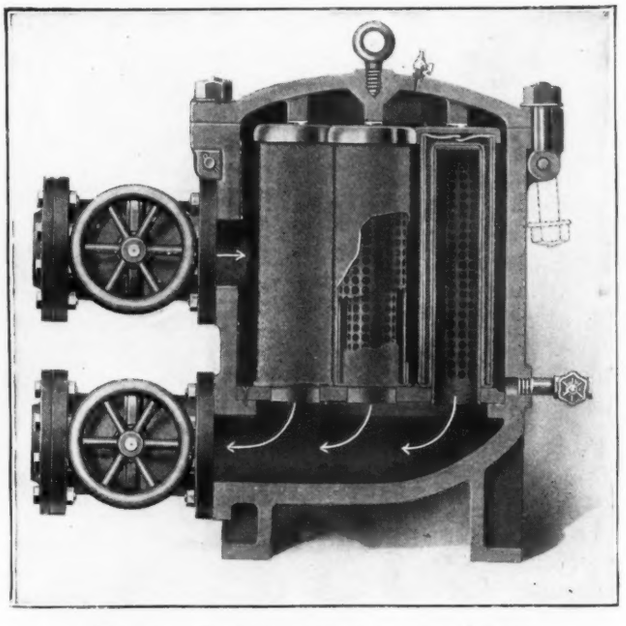


FIG. 2. SECTION THROUGH THE FILTER

by a partition carrying the filtering cartridges. Fig. 2 is a sectional view. The opening of the filter for cleaning is facilitated by the use of a cover held by swing bolts. A crane with a turnbuckle lifts, swings and holds the cover during cleaning.

**Cast Iron**—The average weight of cast iron is taken at 450 lb per cubic goot, or 37.5 per sq.ft., one inch thick.

# Editorials

## The Boiler Code's "Commencement"

College graduation exercises are significantly called "Commencement." To be sure, Commencement marks the completion of the students' college course, but the beginning of their serious or useful life. On page 268 we report the Boiler Code's "Commencement." Its course of preparation is completed and it has obtained the degree of A. S. M. E., which in this case is added before its name instead of after. A great work is done, but another great work is just beginning, without which all the labor of compiling the code would amount to naught, for until the states or municipalities adopt it into their laws and, indeed, until the laws are enforced no real good will be accomplished.

It must be gratifying to those who have given themselves so unselfishly to the task of getting the code in shape, at no inconsiderable expense of time, money and effort, to find many states and cities already eager to avail themselves of this expert assistance in getting proper statutes on their books regulating steam boilers.

This great movement to promote the safety of boiler operation has started auspiciously. As stated in the article referred to, Indiana has already prepared to apply the code and it may even be a part of this state's laws before this issue of POWER reaches its readers. Indiana will thereby have the distinction of being the first to adopt the code after its approval by the council of the American Society of Mechanical Engineers. Wisconsin, however, stole the march on all her sister states by adopting it before its completion, in the law which went into effect January 1, 1915, for this law provides that the code, as soon as approved, shall become a part of it. Pennsylvania and Tennessee have departments already established, administered by the police authority, which promise to adopt the code, and Ohio, now operating under an excellent set of laws, has intimated her intention to revise them to conform with the uniform code. Active work is also being taken up in New Jersey and Florida, and the prospects for other states following suit in the near future are excellent.

To speed the good work of bringing the code to the attention of the law makers a legislative committee has been formed, representing three branches of the boiler-making industry. Its members are: Isaac Harter, Jr., of the Babcock & Wilcox Company, representing the American Boiler Manufacturers' Association; Thomas E. Durban, of the Erie City Iron Works, representing the National Tubular Boiler Manufacturers' Association; and H. P. Goodling, of the Farquhar Company, representing the National Association of Thresher Manufacturers. Thus the water-tube, fire-tube and portable boiler interests have united to bring about with all possible dispatch that condition which will be so much to their advantage—uniform requirements in all localities, so that their product built to meet one standard set of specifications may be used in any part of the country without modification.

That POWER takes a keen satisfaction in this wave of reformation goes without saying. It will not imitate the daily newspapers which delight in attempting to appropriate the credit to themselves whenever a cause they have championed triumphs. While it is only fair to claim that no single institution has so consistently and persistently and for so long a time urged the need of proper laws to safeguard the handling of steam boilers as has POWER, to which its pages for many years back bear witness, it suffices us that the much looked-for end is now in sight, and we are glad to bestow the credit where credit is due. We honor ourselves in saying "well done" to the men who have finally crystallized our cries and those of many others, that there should be laws, into these definite recommendations that these are the laws that should be. With this change of text we shall continue to preach the doctrine and plead for the adoption of the A. S. M. E. code.

## License Activity in New York City

The Mayor and his advisers are bending their efforts to centralize the licensing of buildings, electrical work, engineers and firemen, etc., under one head, namely, the present Bureau of Licenses. As far as the Boiler Squad, which now performs the function of licensing engineers and firemen and of inspecting boilers, is concerned, the proposed plan is to allow it to continue inspecting boilers, while men from the Squad would be assigned to the Bureau to examine applicants for engineers' and firemen's licenses.

Engineers of the city have been alarmed because they understood that all of the functions of the Boiler Squad were to be exercised by another department. Because the present work of the Squad is satisfactory, a change was not looked upon with favor. But the change as proposed by the Mayor's committee is really of little significance as far as the engineers and firemen are concerned. One or two bills covering the function of licensing of various men and kinds of work in the city have been introduced in Albany, but it is too soon to tell just what disposition will be made of them. If passed as originally written the Boiler Squad will become defunct.

It must be admitted that the Police Department is not the logical body to administer the work of inspecting boilers and licensing engineers. The real solution of the question is the creation of a state board to conduct such work. This does not necessarily mean that local boards could not exist contemporaneously, as we point out editorially in this issue.

The Boiler Code Committee of the American Society of Mechanical Engineers in its report just completed, has made quite complete recommendations on uniformity of boiler construction. Probably, before very long, a sup-

plementary report embodying recommendations as to the uniformity of boiler inspection and of the licensing of engineers and firemen will be presented. These recommendations will be scientific. They will be based upon all past experience in such work and will embody the best of all that demonstration has proved good. They will be satisfactory to all of the various interests involved.

The Boiler Squad has been guilty of disreputable acts in the past. It is likely to go wrong again at any time, and those interested would again be confronted with the old conditions. If there must be local boards in New York and Buffalo, the two cities that have combated a state law the hardest, let them have them, but they should conform to the regulations of the state board.

It is not too soon for engineers and owners in New York who are interested in their own welfare and in public safety, to create sentiment favoring a state law embodying the recommendations of the American Society of Mechanical Engineers as to uniformity in construction, inspection and licensing.

## State and Local Inspection Departments

In states where some of the principal cities are already provided with departments for inspecting boilers and examining and licensing engineers, efforts to pass a state law are hampered by the opposition of local politicians and officials, who fear the loss of the patronage and positions which go with the municipal ordinance. There is also to be dealt with the Home Rule sentiment, and the natural reluctance to give up a successful local administration for one administered from the capitol, which would have less direct contact with local men and conditions.

But the state-wide law need not involve the abandonment of the local systems. Most of the state laws either exempt from inspection boilers which are under the care of boiler-insurance companies authorized to do business in the state, or, better, accept the findings of inspectors of such companies after such inspectors have been approved by the state department having charge of boiler inspections, thus becoming pseudo state officials, although in the pay of their respective companies. In this way the state department has a record of all boilers and is as well assured of their satisfactory condition as though they were inspected by men paid by the department itself.

The same principle may well be, and in Wisconsin is, extended to municipal departments. The local board goes on making its own inspections and examinations, granting its own certificates, keeping its own records, and collecting its own fees, but in addition reports to the state department, which is thus able, in connection with its own work in those parts of the state which have no local system, to keep a complete record of all the boilers and engineers in the state and to exercise some supervision over the whole. The state board may, for example, adopt a code of boiler rules, such as that recently completed by a committee of the American Society of Mechanical Engineers, the requirements of which would be enforced by the local and insurance, as well as by their own inspectors. This would result in uniformity of practice, not only as between different parts of the same state, but, it is hoped, as between the states themselves, for state boards would probably avail themselves of the expert work which has been expended upon the production of this code, and all adopt practically the same requirements. An association of the heads of state departments could be a clearing house for information deduced by the investigations and experience of each, and by recommending revisions of the code as the advisability of such revisions develop, maintain substantial uniformity throughout the nation. And the local inspectors would be a part of the system and in line for advancement to the positions of larger responsibility and emolument which it offers.

## The Exposition Opens

February 20 the greatest world's fair to date opened its gates. Our leading article this week is an extensive account of the Exposition, covering somewhat its general features, but more particularly such as will especially interest the engineering field. This is the first of a number of articles which we expect to present, dealing more in detail with the exhibits with which our readers will be concerned, and in the fall an account will be given of the International Engineering Congress, which likewise will be the most notable that has occurred.

The Exposition stands as a commemoration of the greatest piece of engineering in history—the connecting of the Atlantic and Pacific by a canal across the Isthmus of Panama, the benefits of which to mankind will continue down the centuries. The Exposition can hardly have so far-reaching an effect, but if it repeats the experience of like undertakings of the past it will mean much in furthering the progress of all lines of human endeavor by showing what has thus far been accomplished, and thereby indicating the directions in which continued improvement is to be desired.

A fair of this kind is, naturally, of most direct advantage to those who can visit it, and no one who has the opportunity to get to San Francisco should neglect it. It is a liberal education in itself. Next best is to read the descriptions of it which will appear in the periodicals of all kinds. This, too, is an opportunity not to be overlooked. Present-day achievements in the illustrating and printing arts bring within the means of all the ability to gain much of the good that would come from an actual trip to the Fair. But seeing the Fair and reading about it both require a disposition on the part of the individual to avail oneself of the opportunity to broaden one's knowledge.

More indirect, but of certain advantage to the most indifferent, is the influence which such an exposition has on the world at large by stimulating a striving for better things in all lines—art, business, profession or calling of any kind—in consequence of the examples set by the exhibits and in other ways. No one can visit such an impressive collection of the world's best without coming away with new ideas to apply, and these in turn inspire those who do not go.

Innumerable endless chains of uplift are started with every such demonstration of modern achievement. The greater the undertaking, the greater the effect. If argument were needed it could be continued *ad infinitum* to justify all the stupendous labor and expenditure involved in the Panama-Pacific Exposition. Thanks be for the inspiration that conceived the idea and the energy which carried it to fruition!

# Correspondence

## Cost of Steam

H. L. Strong's article on page 133 in the issue of Jan. 26, under the above heading, strikes an important note. Every engineer is interested and anxious to know how much it costs to make steam in the other fellow's plant, but the mere statement that A's steam costs 25c. per thousand pounds does not tell it all. However, it may be used as a basis for comparison and a standard method of arriving at this cost should be used. The statement should contain the following items: Coal, ——— lb. at ———; Water, ——— gal. at ———; Power for Electric-Driven Auxiliaries; Labor; Miscellaneous Expense; Maintenance; Fixed Charges. The first three items are self-explanatory.

Under "Labor" should be charged supervision, foreman, fireman, ash- and coal-conveyor operators, boiler cleaners, ashmen and shovelers, helpers and laborers, and all other labor, aside from maintenance, incident to operating the station.

"Miscellaneous Expense" takes care of oil, waste, etc.

"Maintenance" should include labor and materials required to maintain in proper condition buildings, stokers, conveyors (ash and coal), boiler-room auxiliaries, pipes and fittings, feed pumps, electrical apparatus, and all other tools or apparatus used in the boiler room in connection with making steam.

Under "Fixed Charges" should be charged depreciation of buildings and equipment, insurance (boiler and fire) and taxes.

The sum of these items gives us the total cost of producing steam. This sum divided by the net amount of steam generated, from and at 212 deg. F., and multiplied by 1000, gives the cost per thousand pounds of steam, from and at 212 deg. F. "Net" steam is the steam produced by the boilers which is available for power, etc. It is the total feed water less steam lost by blow-down and that used by boiler-room auxiliaries, or the amount registered by flow meters on the outlet from each boiler, less the steam used by auxiliaries. From records of steam pressure and feed temperature it is a simple matter to reduce to pounds, from and at 212 deg. F.

After following the above form or an equivalent and arriving at the cost of steam per thousand pounds, there are three important items to be considered before the costs in different plants are comparable. These are (1) cost of fuel, (2) load factor, and (3) equipment.

(1) *Cost of Fuel*—If the cost of the coal used in two plants is known and the charges against cost of steam are kept in accordance with the foregoing form, it is a simple matter to adjust the charges and determine what the total costs would be if the fuel costs were the same. For instance: A burns 2000 tons of coal per month, at $4 per ton and his steam costs 28c. per thousand pounds. If his coal cost him $3.50 per ton the total charges for the month would be $1000 less and, consequently, the cost per thousand pounds of steam would be correspondingly lower.

(2) *Load Factor*—The character of the load on a boiler plant has considerable to do with the cost of output. A plant whose load is steady, with small fluctuations, such as a central lighting and power plant, can produce steam cheaper than, say a plant supplying an industry where steam is used for driving engines or turbines, for drying ovens, for miscellaneous manufacturing purposes and for testing manufactured apparatus, under which conditions it may be necessary to carry banked fires under one thousand horsepower or more of boilers. In order to keep costs comparable, the coal used for banking should be kept account of separately from that used for loaded boilers. Only the coal used for actually producing steam should be charged to the cost of steam. This banking, or stand-by, coal should be charged to the departments responsible, and should not be charged to one boiler plant when making cost comparisons with others.

(3) *Equipment*—There is no way of bringing a variety of equipment to a standard basis. However, if the other two factors are made equitable, then, if there is much difference in the cost of producing steam in two plants, it is fair to claim that it is due to equipment and management, and the plant which shows the cheaper production should be given the credit for having the more efficient equipment and organization.

C. W. Howard.

Erie, Penn.

## Purchasing Coal

Under the above caption, in your editorial in the issue of Jan. 26, you say all coal mined must or should be used as fuel. Your argument is good as far as *all coal* is concerned, but if the substance delivered at the plant contains 15 per cent. or more of slate, then the only apparent remedy for this condition is for the consumer to protect himself by the B.t.u. clause in his contract. In the plant of which I have charge we buy all our coal on the B.t.u. basis, and since we adopted this method (three years ago) we show a saving of from 10 to 30 per cent. As to cost of analysis, it is small compared with the saving effected.

Our contract reads $2.20 per ton (2000 lb.) (nut and slack), coal to test 13,400 B.t.u. per pound (100 either up or down not to be taken into consideration), moisture not to exceed 2 per cent., ash not to exceed 10 per cent., samples to be taken with a 2-in. pipe from each load as delivered; part of each sample to be put in a can and sent to a chemist satisfactory to both parties, on the thirteenth and twenty-seventh of each month; consumer to pay for the analysis, which is $3.30 for each sample, or $6.60 per month. There are coal companies that refuse to consider any contract that has this clause included in it, which goes to show that it is a good thing for the consumer.

In January of last year there was a shortage of coal in this city, and dealers took advantage of that condition and boosted the price 50c. per ton, and delivered anything that looked like coal. Of course we got the same grade

of coal that the other plants did, but we were protected by our B.t.u. clause and instead of paying $2.70 and sometimes higher, we paid $1.745. The plant consumed 264 tons that month, which if it had stood up to the guarantee of 13,400 B.t.u. would have cost us $2.20 × 264 = $580.80, but on account of low B.t.u. the price went down to $1.745 × 264 = $460.68, or $114.12 rebate.

Now, suppose we had been like the other fellow and were paying $2.70 per ton, we would have paid $2.70 × 264 = $712.80 for that same coal that cost us $1.745 per ton, or $252.12 more than we actually paid. You must admit that this is a good proposition for the consumer, your employer. If the coal runs above the guarantee of 13,400 B.t.u. you can well afford to pay the premium. To sum the whole matter up, it places the consumer in a position where he can get just what he pays for and pays for just what he gets.

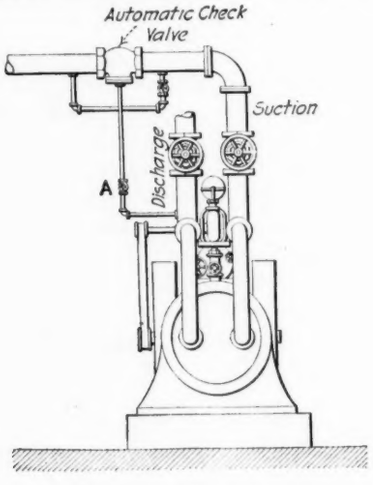
In times gone by the coal game has been in the hands of the dealer, but a B.t.u. contract evens up the game and gives the plant owner an equal show.

O. Newton.

Lakewood, Ohio.

## Compressor Trouble Due to Throttled Suction Line

Several changes had been made in the equipment of a small refrigerating plant, including the addition of a compressor the size of the old one. The new machine did not produce the expected gain in refrigerating capacity; in fact, when run alone on the load it failed to do the same work as the old compressor. It was decided that the suction line was too small to serve the two machines, so a duplicate line was put in. This improved matters but little.




Compressor Connections

The suction gage on the new machine registered 8 lb. lower than the one on the old compressor when running and would increase 3 to 4 lb. after the machine was shut down. There was no gage tester available, so the increase was ascribed to inaccuracy of the gage. This compressor ran much warmer than the old machine.

An automatic check valve was provided in the suction line, as shown. One day when the machine was started the engineer was surprised to hear a hissing sound in the valve similar to that made by steam passing through a throttled valve. He found the bypass open and closed it as it should be in normal operation. This stopped the noise, but did not satisfy the engineer, for he correctly reasoned that if there had not been a considerable difference in pressure on the two sides of the check valve there would have been no hissing sound. He noticed by this time that the suction gage indicated 10 lb. lower on this machine than on the old one, which was 2 lb. greater than it had ever been before; the machine was also hotter than usual.

The valve *A* had been closed when he took charge, and he had been told by several who were supposed to know that it was to be kept closed. He opened it a few turns, and immediately the machine began to pound heavily. He closed the valves, and after a few revolutions the machine ran normal.

The engineer reasoned that there must have been an accumulation of liquid in the suction line back of the check valve, and when he opened the valve *A* this opened the check valve wide, and the accumulated liquid was swept into the machine. He decided to try again, but first he shut off the liquid line to the expansion coils and pumped down until the machines were running hot so as to be sure to prevent slugs of liquid remaining in the suction line. Now he opened the valve *A* gradually. The suction gage jumped from 10 lb. lower than the other gage to 5 lb. above, the machine cooled to the same temperature as the other, and the clattering of the valves that had always been present was silenced.

The trouble was in the check valve. This valve is intended to shut off the suction pressure in case of accident or blowout on the machine or discharge line. It depends on the head, or discharge pressure, to keep it open. The valve *A* being shut, there was little pressure in the pipe leading from it to the check valve, and consequently the check valve was nearly closed, which throttled the flow of gas to the machine. There was a welcome increase in capacity, and the new machine now does as much as the other.

Thomas G. Thurston.

Chicago, Ill.

## Cement as Furnace Lining*

Part of our boiler plant consists of four 90-in. return-tubular boilers rated at 400 hp. each and frequently developing as high as 700 hp. as indicated by the flow meters. Induced draft is used, and the coal burned per square foot of grate averaged, until recently, about 20 lb. One of these boilers has a concrete setting, which in other respects is the same as for the other three boilers, which are brick set. The furnace was lined with firebrick and the bridge-wall was of the same material, but the combustion-chamber walls were bare concrete. These walls were approximately 2 ft. thick and had a 2-in. air space. I have no information as to the mixture, but apparently it was about 1:3:5 cement, sand and crushed stone.

The boiler has been in service twenty-four hours per day for about three-fourths of the time, for about ten years. The furnace lining has been renewed repeatedly, but nothing was done to the setting until a few months ago, when it was found that the combustion-chamber walls had wasted away nearly to the air space; in fact, we cut into the air space in cleaning away the burned

*See "Power," Dec. 15, 1914, p. 840; Jan. 12, 1915, p. 62; Jan. 26, p. 131, and Feb. 2, p. 169.

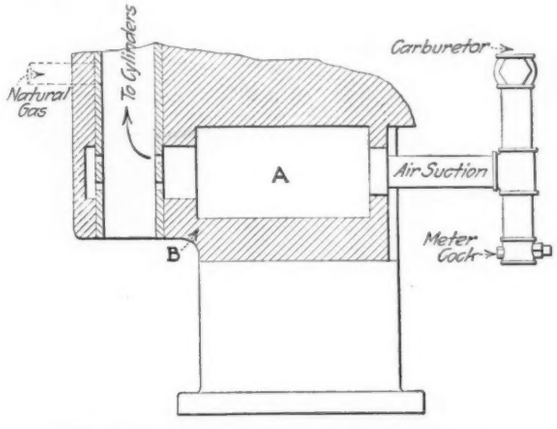
material. The only practicable repair was a brick lining, which was accordingly put in. A new concrete lining could have been put in if there had been sufficient time to allow the concrete to set or harden before using it. In other respects the setting is sound except for two or three old cracks. These boilers have not all been in the same length of time, but the two nearest the age of the concrete-set one have had all or part of the combustion-chamber linings renewed. The worst fault with concrete seems to be the difficulty of repairing, when that becomes necessary and this example seems to indicate that for boilers operated moderately a concrete setting with a fire-brick-lined furnace will last as long as the boiler.

H. L. Strong.

Yarmouthville, Maine.

## Carburetion Trouble

In connecting up, for emergency use on gasoline, a small gas engine that had been operating on natural gas, considerable trouble was experienced at first in getting satisfactory operation. The engine was still to be operated normally on natural gas and was piped so that it could be switched from one fuel to the other by changing valves. The gasoline carburetor was connected to the air suction pipe as shown in the sketch, the other branch of the air pipe having a meter cock in it. By closing the meter cock and the natural-gas valve and




Section through Mixing Chamber

opening the gasoline supply to the carburetor the engine could be run on gasoline; and by shutting off the gasoline supply and opening the meter cock and gas valve it could be run on natural gas.

In running on gasoline it was found necessary at first to give the carburetor needle valve one full-turn opening and after about a half-hour's run the engine would begin to cough, backfire, and slow down. Then if the supply were shut off for a minute it would pick up again and run along all right for about another twenty-minute period, when the backfiring and slowing down would recur. The trouble lay in the fact that the gasoline, having to travel quite a distance from the carburetor through the air pipe and the chamber *A* to the cylinders, would not all stay in the gaseous form, but would partly liquefy and form a little pool in *A*. The engine would draw from this pool as well as from the carburetor, and would get too rich a mixture and start to backfire and slow down.

A small hole was drilled at *B* with the idea that the air suction through it would help to volatilize the gasoline which collected at the bottom of *A*. This helped matters somewhat, but still the operation was not uniform.

The trouble was finally remedied by connecting one end of a flexible metal tube to the air intake of the carburetor, the other end being attached to a "stove" around the engine exhaust pipe at its hottest point. This gave the carburetor hot air, and the gasoline remained in a volatile condition throughout its passage to the cylinders. The operation was then uniform and satisfactory, and the best running point of the carburetor needle valve was found to be one-half turn instead of one turn, as previously.

D. N. McClinton.

Pittsburgh, Penn.

## Emery around a Dynamo

Commenting upon the letter of Mr. Weaver in the Dec. 15 issue on "Emery around a Dynamo," I believe that if his rules and advice were generally followed it would lead to trouble and give repair men plenty of business. The use of emery on either commutators or brushes should be condemned, as even with the utmost care particles of emery are likely to become embedded in the mica, brushes or commutator bars and cause no end of trouble by cutting and scoring the bars or brushes.

The use of oil on a commutator is another bad practice that is far too common. If it is necessary to provide a lubricant for the commutator a brush with a small percentage of graphite should be used. Oil is bound to get into the mica and in time will help carbonize it, causing short-circuits between the bars; which, in turn, will cause the brushes to spark and the commutator to pit and wear.

If a commutator is badly worn or out of true it should be turned off, and if properly done, there will be no need to use a file. After turning, the final finish is obtained by the use of fine sandpaper and any burrs of copper left from the turning can be picked or cut out with the point of a knife or tool. Should the commutator not be in bad enough condition to need turning, it can be trued by "stoning." Sand-stones for this purpose can be obtained in any desired grade and in various shapes; a handy size being 2x2x4 in. in a medium-coarse sand.

In stoning generator commutators the brushes should be lifted and the stone applied with a fair pressure. In the case of motors in operation it can be accomplished the same as sandpapering. After stoning, a finish is obtained by the use of fine sandpaper, and then all dust should be blown off with a bellows or hose and the commutator wiped with a dry rag.

After turning or stoning a commutator it is advisable to fit the brushes. This is done by placing them on the commutator under pressure and running a piece of fairly coarse sandpaper back and forth under the brush with the sand side toward the brush. This will grind the brush down to a surface that conforms to the curvature of the commutator.

There are many different grades of brushes for use for different services. It sometimes occurs that the bars of a commutator are soft and wear faster than the mica, resulting in high mica. An abrasive brush on a commutator of this sort will cut the mica and the bars at an even

rate, or in a case of this kind it is good practice to undercut the mica slightly. Proper undercutting will not cause excessive brush wear. Undercutting is usually advocated on high-speed machines and is rarely resorted to on low- or moderate-speed machines, unless, as has been said, the mica tends to remain high between the bars.

After the commutator of a machine is in good condition it will only be necessary to wipe it off occasionally with a dry rag. The brushes also should be wiped off occasionally, but in the majority of cases should not be removed to do so, as there are few holders in use that will permit of the removal of a brush and its exact replacement relative to the commutator surface. Lifting the brush slightly off the commutator allows wiping it off.

BEN. J. OPPENHEIM.

Bound Brook, N. J.

## Results of Changes in Boiler Furnace

The furnace changes and results obtained, as described in the article of this title by Morgan B. Smith, appearing in POWER, Jan. 19, p. 92, are similar to what was done by Westinghouse Church Kerr & Co. under the writer's supervision at the plant of the Detroit Edison Co., at Delray, Mich., in 1909, 1910 and 1911, which work was referred to in the discussion of Dr. D. S. Jacobus' paper on "Tests of Large Boilers," in the 1911 Proceedings of the American Society of Mechanical Engineers.

In the furnaces at Delray the stoker arches were cut back and the division walls between the stokers were at first constructed so as to come no higher than the fuel bed. Later, we went a step further, eliminating the division walls between the stokers, moving them together so as to present a continuous grate surface across the furnace, and substituting a short flat suspended arch for the customary construction. By these changes all brickwork other than the inclosing walls was removed from the furnaces, the troubles with the arches were eliminated and better combustion conditions were obtained.

It is interesting to note that the results obtained by us some years ago in the furnaces at the Delray plant are confirmed by those reported by Mr. Smith at this later time from the use of a similar construction.

H. O. POND,
Westinghouse Church Kerr & Co.

New York City.

## Decreases the Oil Bill

The work of the power engineer is now primarily concerned with the diminution and prevention of losses more or less secondary in character. One of the best examples of this kind that have come to the writer's attention is that of the lubricating oil for one of the largest New York City office buildings. When this plant was originally installed a high-grade cylinder oil costing about fifty cents a gallon was used, and the oil caught by the separators allowed to run into the sewer.

The first economy was the connecting of all oily drips to a common receiving tank, from which it is pumped to two centrifugal oil separators. These separate the oil and water, the oil being returned to the filters and then to the oiling system. The water is returned to the feed-water heater and from there to the boilers.

The next step was the purchase of graphite lubricators to be used with the cylinder lubricators on the engines, pumps, etc. The graphite lubricators are filled with a paste made of graphite and cylinder oil and connected in between the cylinder lubricator and the steam pipe. The oil from the cylinder lubricator in passing over the graphite picks up enough to form a mixture of graphite and oil, which lubricates the cylinder. As the lubrication is done by the graphite, it is possible to use a much lower grade of oil, because the latter acts principally as a carrying agent for the former. In the case under discussion it was possible to use a 25c. oil, which, with the cost of the graphite, reduced the cost from 50c. to under 30c. per gal.

The separators in handling the oily drips discharge the water and oil as formerly, and also catch and retain the graphite on the plates. These are cleaned every week and the graphite is used in the boilers in place of compound. This system has been in operation for some seven or eight years, and the oil is used over and over without showing any reduction in lubricating qualities. The make-up oil required costs less than $250 a year, and it is calculated that the savings effected pay for the cost of the equipment about once every 11 months. The cost of the separators was about $500 each and the graphite lubricators $15 each. The equipment for this change cost less than $2000 and returns a profit of fully 100 per cent.

W. L. DURAND.

Brooklyn, N. Y.

## Changed Gear Ratio

Changing the gear ratio of a motor drive is not a wise procedure unless the person making the change knows the probable result. A change that will slow the armature may increase its load beyond safe limits, and a change that will make the armature run faster may increase its speed beyond the tensile limit of its band-wires. The folly of random gear changes on direct-current traction vehicles of various kinds can be testified to by some crane and car operators. Induction motors, while similarly subject to overloads incident to decreased gear ratios, offer the assurance that they will never exceed synchronous speed very much, even when driven by the gravitation of their connected load, and will never reach synchronous speed when driven by the current alone. Above synchronous speed, alternating-current motors have a tendency to load themselves by generation.

There are times when changes in gear ratio may be productive of improved operation. An operator of a large locomotive turntable had a gasoline engine installed on one end of the table. The engine did well until traffic increase demanded faster motive power. He then supplemented it with a three-phase induction motor, installed on the opposite end of the table. The motor handled the work twice as fast as the engine had, but for several reasons, including variable voltage, variable frequency and abusive handling, it began to give trouble by heating. Ammeters showed that the motor was never overloaded except at starting, but that it was starting a large proportion of the time. To ease the starting, the gear ratio was increased 20 per cent. This stopped all trouble without materially affecting the speed of operation, because the armature ran faster.

J. A. HORTON.

Schenectady, N. Y.

# Inquiries of General Interest

**Highest Temperature of Feed Water with Open Heater**—Why cannot the temperature of water in an open feed-water heater be raised higher than 212 deg. F.?

H. R.

Because the water is under atmospheric pressure, and 212 deg. F. is the temperature at which water is converted into steam at that pressure.

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**Relative Transmission by Rubber and Leather Belting**—What thicknesses of rubber belting are equal for transmission of power to single and double leather belts?

R. C.

When made of cotton duck weighing two pounds per yard coated with best India rubber, 3- and 4-ply rubber belting is usually taken as equal to single leather belting and 5- and 6-ply as equal to double leather belting.

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**Total Heat of Steam**—What would be the total heat of a pound of steam at gage pressure of 100 lb. per sq.in., with a barometric pressure of the atmosphere of 28.5 in. and temperature of 62 deg. F.?

S. G.

One inch of barometric pressure at 62 deg. F. is equal to 0.491 lb. per sq.in., and therefore the absolute pressure of the boiler steam would be

$$100 + (0.491 \times 28.5) = 113.99$$

or practically 114 lb. absolute, and according to Marks and Davis' steam tables, a pound of steam at the latter pressure would contain 1188.7 B.t.u. above 32 deg. F.

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**Wetter Steam Requires More Feed Water**—When our boiler is pushed to its highest capacity, why is it that the water level gradually goes down, but as soon as the damper is partly closed and with the feed pump operating at the same speed, the boiler-water level comes up again?

C. J. P.

It is quite likely that when the boiler is forced wetter steam is generated, and although doing the same amount of work, greater weight of steam of the lower quality is discharged from the boiler, thereby requiring replenishment of feed water in excess of the rate required for maintaining the proper water level with the damper partly closed.

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**Regulation of Oil Burners**—In the use of oil burners how can the best regulation of the oil, steam and air supply be determined?

A. C. S.

The best regulation of oil burners is obtained by observation of the top of the smoke-stack and the color of the fire. When the burner valves and the air supply are correctly adjusted, the flame is a bright white and there is no smoke. When the supply of steam is too great, steam will appear around the burning spray and will be discharged from the smoke-stack. If too little steam is being used, atomization will be incomplete, and if the air supply is insufficient the color of the flame will be red, and incomplete combustion will be indicated by the discharge of smoke from the stack.

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**Advantages of Extended Front Boiler Setting**—What are the advantages and disadvantages of an extended front setting as compared with a flush front setting for a horizontal return-tubular boiler?

W. C.

The principal advantages of the extended front are the employment of a shorter brick setting and obviation of passage of the furnace gases direct to the front smoke connection, as is likely to occur with a flush front setting, from settling of the fire-door arch or other causes of leakage of the joint between the fire-door arch and the under side of the boiler. The disadvantages are that with a low setting the front extension may be in the way of the fireman, and also that the extended front does not present as good an appearance as the flush front.

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**Depth of Front and Back Connections for Return-Tubular Boilers**—What should be the depth of front and of back smoke connections for horizontal return-tubular boiler settings?

G. R.

The depth of back connections for any size of boiler should be not less than 24 in., so as to allow sufficient space for examination and expansion of tube ends in the back tube sheet, and for boilers larger than 66 in. in diameter the depth of back connections should be not less than 28 in. Greater depth is advantageous for equalizing the distribution of the heated gases to all tubes of the boiler. Front connections should be of such form and depth as to permit of an easy sweep of the gases to the uptake. The minimum depths should be 12 in. for boilers up to 54 in. diameter, 16 in. for boilers 60 and 66 in. diameter, and 18 in. for boilers 72 and 78 in. diameter.

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**Operation of Centrifugal and of Inertia Governors**—What is the difference between the operation of centrifugal and of inertia governors?

J. E. B.

In centrifugal governors a change in position of the governor parts is effected solely by a change of centrifugal force resulting from a change of speed. In inertia governors, revolving weights are so arranged that when the engine wheel is accelerated, as by removal of load, the inertia of the weights causes them to lag behind and assist centrifugal force in adjustment of the valve gear for admission of less steam, thus checking the speed, while if the speed of the wheel is retarded, as by an increase of load, the momentum of the weights causes them to surge ahead and assist the spring action of the governor to attain a position of parts that will increase the speed. Therefore, inertia governors are prompter than centrifugal governors, and also may be more powerful and closer in regulation.

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**Air Required for Burning a Ton of Coal**—What volume of air should be supplied for burning a ton of coal?

B. S.

Most fuels require between 11 and 12 lb. of air per pound of fuel, according to their analyses, and it is usual to consider that 12 lb. of air will be required to burn each pound of coal. But to make sure that each atom of carbon will meet with an abundance of oxygen, it is necessary to admit an excess of air to the furnace, the amount depending on the force of the draft. With natural draft at least twice as much and with forced draft at least 1½ times as much air will be required. As one pound of air at 62 deg. F. has a volume of 13.14 cu.ft., then for burning a ton (2000 lb.) of coal the air supply should be not less than

$$12 \times 2 \times 13.14 \times 2000 = 630{,}720 \text{ cu.ft.}$$

of air with natural draft, nor less than

$$12 \times 1\tfrac{1}{2} \times 13.14 \times 2000 = 473{,}040 \text{ cu.ft.}$$

of air with forced draft.

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**Loss of Water Level in Gravity-Return Boiler**—What may be the cause and remedy for occasional loss of proper water level in the sectional boiler of a low-pressure gravity-return steam-heating apparatus?

H. B. L.

The proper water level will not be maintained by automatic return of the water of condensation to the boiler when the temperature of steam in the pipes or radiators is so much reduced by radiation of heat that the pressure, plus the static pressure of the return connection, is less than the sum of the pressures required for overcoming pipe friction, and opening the return check valve added to that in the boiler. Under these conditions the water level may also become reduced by the water of the boiler backing up into the system through leakage of the return check valve. The remedy is to obtain higher relative pressure in the return water by increasing the sizes of steam supply pipes or increasing the static pressure of the return water by raising the level of pipes and radiators or lowering the boiler.

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[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—EDITOR.]

# The Elasticity and Endurance of Steam Pipes*

By C. E. Stromeyer

In the present paper it is proposed to inquire into the causes of steam-pipe failures by dealing with about a hundred reported explosions which have been attributed to fatigue and to want of elasticity, though it may have to be admitted that bad material and workmanship, including injudicious or unnecessary annealing, have occasionally either accelerated the failures or have been their chief causes.

In dealing with this subject it will first be necessary to fix on a standard of comparison for the fatigue stresses which may have caused the failures; but in order not to complicate this subject, and also because definite information is not available, it will for the present be assumed that Guest's law for steel also applies to copper, which means that the circumferential stresses in pipes, due to internal steam pressures, do not affect the bending stresses which in the cases under consideration have caused the fractures. Then, also, nothing is as yet known about the influence of temperature on the power of copper to resist fatigue stresses, though it is probable that it has a weakening effect; but temperature also increases the elasticity of copper, so that as regards deformations due to fatigue stresses no serious error will be committed by leaving these two temperature influences out of account.

According to experiments the relationship between the fatigue stresses ($\pm S$) and the number (N) of the stress cycles (revolutions) which cause fracture is expressed by the formula

$$\pm S = Fl + C\,(10^6 \div N)^{\frac{1}{2}}$$

Here C is a constant depending on the nature of the material and Fl is the fatigue limit of the material. Both Fl and C have been obtained by breaking a number of samples by fatigue stresses and marking off the test results on diagrams in which the ordinates were spaced to represent $(10^6 \div N)^{\frac{1}{2}}$. The test results were then found to lie on straight lines which, when prolonged, cut the zero ordinate at the heights Fl, which were then adopted as being the fatigue limits. These tests could naturally not have been continued to an infinite number of revolutions, and there was therefore no absolute certainty that this exterpolated fatigue limit was a reality until by improved methods of testing this point was firmly established. In other words, more recent experiments have demonstrated the fact that this formula applies not only within the range of previous experiments, say from two thousand to twenty million alternations of stress, but also to an infinite number. Wöhler's experiments, and in fact all past experiments which have been examined, confirm the above-mentioned formula.

Wöhler's experiments confined themselves to steels, except one series of tests on wrought iron, but they have been extended by the author to embrace, at least as regards torsion-fatigue tests, about fifty different qualities of steel and steel alloys, cast and wrought iron, nickel, copper, aluminum, phosphor bronze, magnalium, and other alloys, and in all cases the test results harmonized with the formula, which may therefore be accepted as correct. A matter of even greater importance than the general form of the formula is that the fatigue limit can now be expeditiously determined with greater accuracy even than the static tenacity. In one case its extreme values among eight test pieces cut from one crankshaft differed by less than $\pm 0.4$ per cent. of the mean value.

Unfortunately no bending fatigue tests have been made on copper, but this omission will be made good in the near future, and the determination of the fatigue stresses which caused fractures in copper pipes will therefore have to be based on deductions drawn from a few torsion-fatigue tests on copper bars which are summarized in the following formula, in which $\pm$ St is the alternating shearing stress due to torsion strains which cause failure at the nth revolution:

| | |
|---|---|
| Copper bar as rolled | $\pm St = 5.4 + 0.37\,(10^6 \div N)^{\frac{1}{2}}$ |
| Copper bar as rolled | $\pm St = 5.6 + 0.51\,(10^6 \div N)^{\frac{1}{2}}$ |
| Mean of above | $\pm St = 5.5 + 0.44\,(10^6 \div N)^{\frac{1}{2}}$ |
| Copper bar annealed in vacuo | $\pm St = 2.55 + 0.87\,(10^6 \div N)^{\frac{1}{2}}$ |
| Copper bar annealed and chilled in water | $\pm St = 2.69 + 0.97\,(10^6 \div N)^{\frac{1}{2}}$ |

It having been found that on an average the bending fatigue limit for steel is about 60 per cent. higher than for torsion, the last of the above torsion-fatigue limits may reasonably be increased from 2.69 to 4.30 tons per square inch for the bending-fatigue limit for copper, and as the same comparative tests on steels show that the value of C for bending is three and a half times as great as that for torsion, the value of $C = 0.97$ may be increased to 3.4 tons per square inch and the formula for the bending-fatigue stresses of copper is probably

$$\pm Sb = 4.3 + 3.4\,(10^6 \div N)^{\frac{1}{2}}$$

As wrought-iron and mild-steel pipes are now largely used on steamers, formulas for their bending-fatigue stresses are of interest. Among the writer's own tests he finds the following results for basic steel, which is the quality of which many welded-steel pipes seem to be made:

TABLE I

| | Fatigue Limit, Tons per Sq.In. | Values of C, Tons per Sq.In. |
|---|---|---|
| British ordinary | 9.69 | 4.53 |
| British dead soft | 11.26 | 3.92 |
| German ordinary | 11.34 | 4.10 |
| German dead soft | 8.94 | 4.79 |
| Mean for mild basic steel | 10 31 | 4.33 |

It will be noticed that the fatigue limit for the softer qualities of basic steel, which contain about 10 per cent. carbon, are not necessarily lower than those for ordinary mild qualities, which have about 40 per cent. carbon. This is due to the presence of varying percentages of nitrogen, which element has a tenfold greater influence than carbon on the fatigue limit. The fatigue limit for cast steel is only a little higher than the above, viz., about twelve to thirteen tons per square inch.

The formula for the bending-fatigue stresses of mild steel may therefore be written

$$\pm Sb = 10.30 + 4.33\,(10^6 \div N)^{\frac{1}{2}}$$

Only one set of bending-fatigue tests has been made on wrought iron (by Wöhler). The results can be expressed by the formula.

$$\pm Sb = 6.73 + 4.43\,(10^6 \div N)^{\frac{1}{2}}$$

Among the Board of Trade reports on steam-pipe failures there are none which may be attributed to fatigue of mild steel, but there are a fairly large number of failures of copper pipes, of which a few are capable of being analyzed with the help of the above formula. The following are the report numbers of the failures in question—failures said to be due to vibrations:

Straight pipes—Nos. 948, 1113.

L-bends, like Fig. 6—Nos. 453, 854, 945, 958, 1024, 1049, 1057, 1095, 1111, 1164, 1181, 1187, 1207, 1291, 1296, 1491, 1516, 1611, 1651, 1795, 1852, 1895, 1931.

U-bends, like Fig. 9, without central branch—Nos. 480, 1011, 1021, 1069, 1172, 1185, 1313, 1426, 1435, 1501, 1922, 2105.

U-bends, with central main pipe at right angles to bend, similar to Fig. 9—Nos. 970,992, 1015, 1036, 1696.

S-bends and two L-bends placed at right angles to each other—Nos. 657, 718, 749, 772, 775, 915, 1290, 1527, 1654, 1709, 1926, 1993.

Expansion bends with straight lengths—Nos. 767, 943, 1616, 1795, 1852, 1895, 1931.

The following failures are probably due to looseness of the engine or the boilers:

Engine seating loose—Nos. 742, 833, 1013, 1160, 1355, 1443, 1666, 1922, 1964, 2021, 2088. (In these cases it is presumable that the movements were appreciably great and as numerous as the revolutions of the engines, which on an average may be assumed to be 60 per minute for six months a year.)

Boilers loose—Nos. 543, 728, 1210, 1467. (In these cases it is probable that the movements were large but few, and the empirical rule for the fatigue stresses does not apply.)

Relative movement between boilers or engines and the ship's structure—Nos. 1268, 1543, 1291, 2176.

Shaft brake and engine raced violently—No. 1216. (This pipe had many bends, otherwise the stresses might have been estimated.)

Most of the aforementioned cases cannot profitably be analyzed on account of complexity of form and absence of details. However, Nos. 958, 1049, 1181 and 1954 of the first group and Nos. 1355, 1543 and 2021 of the second group are suitable for this purpose. The estimated fatigue stresses which fractured the aforementioned ten pipes are contained in Table II.

No allowances have been made for the internal steam pressures and their temperatures, though with the exception of

*Paper read before the Institution of Naval Architects and abstracted from "Engineering," London.

2021, for which the steam pressure was 200 lb., the pressures in all the cases were 160 lb.

Case No. 1954 deserves special attention, for the estimated fatigue stresses are approximately equal to the static tenacity of copper. The fact that this pipe withstood these alternative stresses for four hours suggests either that the adopted value of C = 3.4 tons per sq.in. per 1,000,000 revolutions is too high or that the copper was of a harder quality than usual. Among the 200 cases of steam-pipe explosions reported on by the Board of Trade, only three have been found in which measurements of movements which may have caused the failures are given.

TABLE II. ESTIMATED FATIGUE STRESSES UNDER WHICH CERTAIN COPPER PIPES FAILED AFTER N REPETITIONS

| Report Number | Age at Time of Fracture | Assumed Number of Revolutions | $(10^6 \div N)^{\frac{1}{7}}$ | Estimated Fatigue Stresses, Tons per Sq.In. | Remarks |
|---|---|---|---|---|---|
| | | Failures due to Vibrations of the Engines | | | |
| 958 (1) | 12 months | 15,000,000 | 0.505 | 6.02 | Starboard pipe |
| 958 (2) | 25 months | 31,000,000 | 0.423 | 5.74 | Port pipe |
| 1049 (1) | 2½ years | 40,000,000 | 0.397 | 5.65 | First failure |
| 1049 (2) | 1 year | 15,000,000 | 0.505 | 6.02 | Second failure |
| 1181 (1) | 10 years | 150,000,000 | 0.285 | 5.27 | First failure |
| 1181 (2) | 24 hours | 86,000 | 1.846 | 10.57 | Heavy weather |
| 1954 (1) | 8½ years | 120,000,000 | 0.302 | 5.33 | First failure |
| 1954 (2) | 4 hours | 14,000 | 2.900 | 13.85 | Engines racing |
| | | Failures due to Loose Engine Seatings | | | |
| 1355 | 35 months | 44,000,000 | 0.388 | 5.62 | Long bend |
| 1543 | 4 years | 60,000,000 | 0.359 | 5.52 | U-bend secured to deck beam |
| 2021 | 3 years | 45,000,000 | 0.386 | 5.61 | Long bend |

TABLE III (Figs. 1 to 5).

| | Estimated Inclinations a | Estimated Displacements δ x | Estimated Displacements δ y |
|---|---|---|---|
| Fig. 1 | $+ M \times L \div E \times I$ | ..... | $+ \frac{1}{2} M \times L^2 \div E \times I$ |
| Fig. 2 | $+ \frac{1}{2} Y \times L^2 \div E \times I$ | ..... | $+ \frac{1}{3} Y \times L^3 \div E \times I$ |
| Fig. 3 | $+ \frac{1}{2} \pi M \times R \div E \times I$ | $- 0.571 M \times R^2 \div E \times I$ | $+ M \times R^2 \div E \times I$ |
| Fig. 4 | $- 0.571 X \times R^2 \div E \times I$ | $+ 0.356 X \times R^3 \div E \times I$ | $- \frac{1}{3} X \times R^3 \div E \times I$ |
| Fig. 5 | $+ Y \times R^2 \div E \times I$ | $- \frac{1}{2} Y R^2 \div E \times I$ | $+ \frac{1}{4} \pi Y \times R^2 \div E \times I$ |

M is the external bending moment shown in Figs. 1 and 3; X is the external horizontal pull shown in Fig. 4; Y is the external vertical pull shown in Fig. 5; E is the modulus of elasticity, say 13,000 tons per sq.in. for wrought iron and steel, 8300 for copper, and 4500 to 8000, or say 6000, for cast iron; I is the moment of inertia of the section of the pipe and is equal to $(D^4 - d^4)\ n \div 64$, where D is the external and d the internal diameter of the pipe; a, δ x, and δ y are the acquired inclination and the displacement of the ends of the pipe (see Figs. 1 to 5); Sb, the maximum bending stress for any moment M, is ½ M × D ÷ I, which expression can be introduced in the formulas when the movements produced by X and Y are known.

One application of these formulas can be illustrated with the help of Fig. 6, which represents half a U-bend. Assume, as was the case in Prof. Bautlin's experiments, which will shortly be dealt with, that the flange A, which is the middle of the bend, is a fixture and that a pull X is acting horizontally on the flange C. Then the bending of BC is the same as that in the curved pipe in Fig. 4, X being applied as in that figure. The bending of AB is represented by the two cases, Figs. 3 and 5, M being equal to XR and Y equal to X. Then the acquired inclination of a of the flange B is according to the third and fifth lines of Table III:

$$a = (\tfrac{1}{2}\pi\ R \times X \times R \div XR^2) \div E \times I = 2.571\ X \times R^2 \div E \times I.$$

The displacement Δ of the flange C is the sum of the displacement δ y of Figs. 3 and 5, of δ x of Fig. 4, and of the product of the inclination a into the radius R of the bend BC

$$\Delta = (X \times R^3 + 0.785\ X \times R^3 + 0.356\ X \times R^3 + 2.571\ X \times R^3) \div E \times I = 4.713\ X \times R^3 \div E \times I.$$

The bending moment at A is of course 2X × R, and this is equal to S × I ÷ ½D, where D is the external diameter of the pipe. On replacing I by X2R × D ÷ 2S, the stress S at the flange A can be expressed in terms of the displacement Δ:

$$S = \Delta \times D \times E \div 4.712\ R^2$$

For copper, the value of E is about 8300 tons per sq.in., so that for pipes of this material $S = 1750\ \Delta \times D \div R^2$, and assuming 4.3 tons per sq.in. as being the fatigue limit for copper, the maximum permissible movement of half a copper U-bend (Fig. 6) should not exceed

$$\Delta_c = R^2 \div 405\ D$$

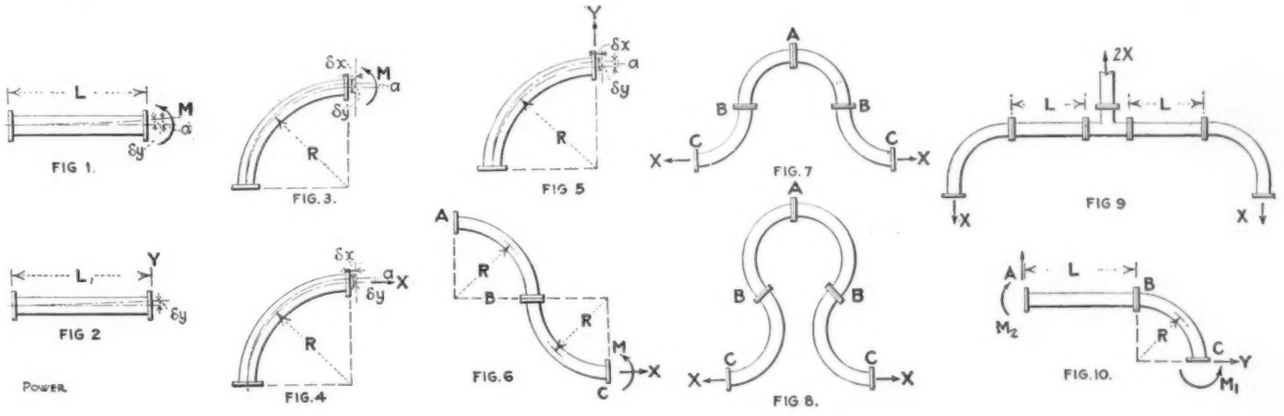
For steel and wrought iron E = 13,000, and therefore $S = 2750\ \Delta \times D \div R^2$, and assuming the fatigue limit for wrought iron to be 6.75 tons per sq.in., we have

$$\Delta_I = R^2 \div 410\ D \text{ for wrought iron}$$

Assuming a fatigue limit of 10.3 tons per sq.in. for mild steel, we have

$$\Delta_S = R^2 \div 265\ D$$

Thus a U-bend (Fig. 7) of 8 in. diameter and 8 ft. high which forms part of a long length of pipe will take up the following expansion movements without injury to itself: 1.40 in. if of copper, 1.40 in. if of wrought iron, and 2.20 in. if




THE LETTERS CORRESPOND TO THOSE IN THE ALGEBRAIC EXPRESSIONS IN THE TEXT

Report No. 1467 mentions that the boiler rolled ½ in. Report No. 1296 mentions that when getting up steam the length between the two valves (no dimensions given) shortened by 0.47 in., and the difference of level between the two valves altered by 0.44 in., the boiler top having risen $\frac{5}{16}$ in. as compared with the ship's structure and the engine stop-valve, which had risen ⅛ in. The history of this pipe is interesting. It was made of solid-drawn copper and put in service in July, 1899; it cracked near its flange Jan. 17, 1900 (five and one-half months' interval). The cracked end was cut off and replaced by a sleeve, which cracked nine hours after lighting the fires. A new sleeve of thicker copper (¼ in.) was now fitted, which ran, say, from the end of February to July 30, 1900 (about five months), and then cracked. A new pipe with a larger bend was fitted (August, 1900), but this pipe cracked (no date given). The crack was repaired and the gland made workable. These several failures seem to have been due, not to frequent movements associated with the revolutions of the engine, but to steady stresses caused by the difference of expansion of the boiler and engine, intensified by the vibrations of the engine. No experimental data as to the endurance of copper under these conditions are yet available.

No. 1318 reports that the boiler top rose up $\frac{5}{16}$ in. and the engine ¼ in. due to the raising of the steam pressure, the two boilers separated by ⅛ in., and the distance between the engine and one boiler stop-valve was reduced by $\frac{5}{16}$ in. In this case the explosion was due to imperfect brazing of one of the flanges.

To understand the stresses which arise when pipes are strained, the several possible deformations of straight and curved pipes, as represented in Figs. 1 to 5, have been expressed mathematically in Table III.

of mild steel. This last result agrees with experiment A in Tables IV and V.

TABLE IV. PROFESSOR BAUTLIN'S EXPERIMENTS ON THE ELASTICITY OF BENDS

| Details of Bends | Height, In. | Outside Diameters and Thicknesses, In. | Moment of Inertia I | M.I. Millions |
|---|---|---|---|---|
| A, mild steel pipe..... | 94.7 | 8.7 × 8.2 × 0.26 | 27.0 | 810 |
| B, mild steel pipe..... | 88.8 | 5.3 × 5.1 × 0.175 | 2.65 | 80 |
| C, cast-iron pipe..... | 94.7 | 8.5 × 8.4 × 0.78 | 139.0 | 275 |
| D, mild steel rod..... | 54.6 | 3.14 square | 8.0 | 240 |
| E, mild steel rod..... | 62.5 | 3.14 square | 8.0 | 240 |

Prof. Bautlin carried out some experiments on U-bends shaped as shown in Fig. 8*. As the bends were not square other but similar formula to the above had to be constructed for estimating the displacement of the flange C. These are recorded in the columns marked "Est." in Table V. The observed displacements are to be found in the columns marked "Obs." The modulus of elasticity of the cast-iron pipe was 7870 tons per sq.in.

The formula for these bends is

$$\Delta = 17.27 \times \times R^3 \div E \times I \text{ and } S = \Delta \times D \times E \div 17.27\ R^2$$

It must not be overlooked that whereas in the previous case (Fig. 7) the height of the bend is 2R, in the present case (Fig. 8) it is 3.414 R. The agreement for the mild-steel rods between the estimated and observed displacements is satisfactory, but pipes seem to be rather more elastic than was expected. The discrepancies between the estimated and the observed displacement for the mild-steel pipe A have been explained as being due to slight puckers on the insides of the bends of the pipes. In part they are also due to the thinning during the bending operation. Generally speaking, Professor Bautlin's important experiments confirm the mathematical estimates of the deformations of bent pipes, and these may therefore be applied to the few exploded steam-pipes for which the probable alternating stresses have already been calculated. It is unfortunate for the present investigations that the Board of Trade reports contain so little information about those parts which, in the opinion of the reporting surveyors, are not the direct causes of the explosions. Among about one hundred reports on steam-pipe explosions, which it is believed were brought about by want of elasticity, the diameters of the pipes and the thicknesses at the points of fracture are given, but rarely is any mention made of the lengths or the elasticities of these pipes, although these are the determining factors.

For the purpose of this paper, these lengths, as well as the radii of curvature, had to be approximately ascertained by scaling them with the help of the diameters as sketched. It is therefore possible that the dimensions which have been adopted in the following calculations are not always correct.

U-bends (Fig. 9) with central branch do not seem to have failed, and this form need not be discussed.

L-bends and simple U-bends (see Fig. 10). The following formula for the displacement $\delta y$ in the case of L-bends and $2\,\delta y$ for U-bends can be determined in terms of the horizontal pull Y and the bending moment M by combining the formula in Table III for the cases represented by Figs. 1, 2 and 5. As there is no pull X, and as the sums of the deflections of the length L and the bend is zero, Y can be eliminated and M expressed in terms of Sb, the maximum bending stress.

$$\delta y = 0.712\, S_b \times R^2\,(L + 0.65\,R) \div E \times D\,(L + R)$$

For copper E = 8300 tons per sq.in., so that

$$\delta y = S_b\,R\,(L + 0.65\,R) \div 11{,}600 \times D \times (L + R)$$

This formula has been used in calculating the displacements $\delta y$ for the following L-bends and $2\,\delta y$ for U-bends, Sb being the fatigue stresses which have been previously determined for the separate cases.

Report No. 958 deals with the two separate L-bends made of electro-deposited copper of 5 in. external diameter hooped with iron bands. The shorter length, in which, according to the sketch, L and R seem to be respectively about 11 in. and 57 in., failed after 12 months' service. Assuming the correctness of the previously found alternating stresses of ± 6.2 tons per sq.in., the relative movements of the two ends of the pipe should by the formula be ± 0.38 in. In the longer branch, L and R seem to be respectively 75 in. and 68 in. Assuming the correctness of the previously found stresses of ± 5.74 tons per sq.in., the relative movements of the pipe ends should be ± 0.25 in.

Report No. 1049 deals with another L-bend of solid-drawn copper of 5¾ in. external diameter. According to the sketch, L and R seem to be respectively 80 in. and 25 in. Assuming the correctness of the previously found alternating stresses of ± 5.65 tons per sq.in. for the first failure after 2½ years' running, the relative movements of the two ends of the pipe should be 0.049 in., and for the second failure after 12 months' running the alternate stresses would be ± 6.02 tons and the relative movements should be 0.051 in. The comparative smallness of these relative movements is due to the rigidity of the small bend, which was only five times as large as the diameter of the pipe. In fact, the pipe probably acted as a stay between the engine and the boiler and restricted their movements while being fatigued. Had the relative movements been larger and the stresses more intense, the failures would have occurred sooner, as happened in the following two cases:

Report No. 1181 deals with an L-bend of solid-drawn copper 6⅞ in. external diameter. According to the sketch, L and R seem to be respectively 42 in. and 50 in. Assuming the correctness of the previously found alternating stresses of ± 10.57 tons per sq.in. for the failure, which occurred after 24 hours' heavy service immediately after previous annealing, the relative movements of the ends of the pipe should be 0.27 in. Seeing that the estimated alternating stresses during the previous ten years' running were only ± 5.27 tons per sq.in., the relative movements of the pipe ends during this longer period do not seem to have exceeded ± 0.14 in.

Report No. 1954 deals with an L-bend of sheet-copper 4.92 in. external diameter. According to the sketch, L and R seem to be respectively 93 in. and 32 in. Assuming the correctness of the previously found alternating stresses of ± 13.85 tons per sq.in. for the new pipe, which failed during a run of four hours in heavy weather, the relative movements of the ends of the pipe should be ± 0.23 in. For the old pipe, which failed after eight years' running under stresses of ± 5.33 tons per sq.in., the relative movements should be ± 0.09 in.

Report No. 1355 deals with an L-bend of solid-drawn copper 5.19 in. external diameter. According to the sketch, L and R seem to be respectively 70 in. and 100 in. long. Assuming the correctness of the previously found alternating stresses of ± 5.62 tons per sq.in., the relative movements of the ends of the pipe should be ± 0.39 in.

Report No. 1543 deals with a U-bend of solid-drawn copper 4.94 in. external diameter. Judging by the sketch, L and R seem to be respectively 16 in. and 46 in. long. Assuming the correctness of the previously found alternating stresses of ± 5.52 tons per sq.in., the relative movement of the ends of the pipe should be ± 0.26 in.

Report No. 2021 deals with an L-bend of solid-drawn copper 5.5 in. external diameter and 0.25 in. thick. According to the sketch, L and R seem to be respectively 68 in. and 42 in. Assuming the correctness of the previously found stresses of ± 5.1 tons per sq.in., the relative movements of the ends of the pipe should be ± 0.17 in.

TABLE V. PROFESSOR BAUTLIN'S TEST RESULTS

| | Difference between two Successive Thrusts in Pounds: 220. | | 440 | | 660 | | 880 | | 1325 | | 1980 | | 2420 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Estimated and Observed Displacement of Flange C. Inches | | | | | | | | | | | | | |
| | Est. | Obs. | Est. | Obs. | Est. | Obs. | Est. | Obs. | Est. | Obs. | Est. | Obs. | Est. | Obs. |
| A..... | .... | .... | .... | .... | 0.30 | 0.68 | .... | .... | 0.60 | 1.37 | 0.90 | 2.16 | 1.10 | 2.96 |
| B..... | 0.84 | 0.69 | 1.67 | 1.42 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| C..... | .... | .... | 0.06 | 0.10 | .... | .... | 0.12 | 0.22 | 0.17 | 0.33 | .... | .... | .... | .... |
| D..... | .... | .... | .... | .... | 0.19 | 0.24 | .... | .... | .... | .... | .... | .... | .... | .... |
| E..... | .... | .... | .... | .... | 0.30 | 0.33 | .... | .... | .... | .... | .... | .... | .... | .... |

The elastic limit was reached with pipe A with a thrust of 1809 lb.

TABLE VI. ESTIMATED INTENSITIES OF FATIGUE STRESSES AND THE RELATIVE MOVEMENTS OF THE ENDS OF THE FRACTURED PIPES

| Report Number | Assumed Number of Vibrations | Estimated Fatigue Stresses, Tons per Sq.In. | Estimated Fatigue Movements, In. |
|---|---|---|---|
| Failures Due to Vibrations of the Engines | | | |
| 958 (1)..... | 15,000,000 | ± 6.02 | ± 0.38 |
| 958 (2)..... | 31,000,000 | ± 5.74 | ± 0.25 |
| 1049 (1)..... | 40,000,000 | ± 5.65 | ± 0.049 |
| 1049 (2)..... | 15,000,000 | ± 6.02 | ± 0.051 |
| 1181 (1)..... | 150,000,000 | ± 5.27 | ± 0.14 |
| 1181 (2)..... | 86,000 | ± 10.57 | ± 0.27 |
| 1954 (1)..... | 120,000,000 | ± 5.33 | ± 0.09 |
| 1954 (2)..... | 14,000 | ± 13.85 | ± 0.23 |
| Failures Due to Loose Engine Seatings | | | |
| 1355..... | 44,000,000 | ± 5.62 | ± 0.39 |
| 1543..... | 60,000,000 | ± 5.52 | ± 0.26 |
| 2021..... | 45,000,000 | ± 5.61 | ± 0.17 |

*Zeitschrift des Vereins Deutscher Ingenieure, 1910, Vol. 54, page 43. Also Mitteilungen über Forschungsarbeiten des Vereins Deutscher Ingenieure, Vol. 96.

These and the previous estimates are summarized in Table VI. They are all based on the empirical formula which correlates the fatigue stresses for copper and the number of their repetitions up to the point of failure. The experiments on which it is based are comparatively few, and more comprehensive ones will shortly be carried out on a new fatigue-testing machine which is nearing completion; but seeing that the results of fatigue tests with mild steel are consistent, the intended further experiments on copper will probably merely confirm those already obtained.

Assuming the correctness of the empirical formula, then, judging by the estimates contained in Table VI, relative movements between engines and boilers of ±0.38 in. (see No. 958) or more should be allowed for. These were associated with fatigue stresses of ± 6.02 tons per sq.in., which exceed the fatigue limit of ± 4.3 by 1.7 tons per sq.in. If these relative movements of ± 0.38 in. had not exceeded ± 0.27 in., the pipe would not have failed. Had the pipe been made of steel it would also not have failed, for although its modulus of elasticity is 13,000, as against 8300 tons per sq.in. for copper, the respective fatigue limits are 10.3 and 4.3 tons per sq.in., and the maximum relative movement to which such a steel pipe would have submitted without injury would have been ± 0.43 in. Conversely, if a steel pipe of the above dimensions were replaced by a copper one and the relative movements of its ends were maintained at ± 0.43 in., then the fatigue stresses in the copper pipe would be ± 6.77 tons per sq.in., or ± 2.47 tons above the fatigue limit of ± 4.3 tons, and the copper pipe would fail after 3,600,000 repetitions. This means that if any copper pipe were to fail after experiencing 3,600,000 stress cycles, which corresponds to 42 days' continuous running of the engines at 60 revolutions per minute, and if it were to be replaced by a steel pipe, this would last forever, and as most of the pipes dealt with in the Board of Trade reports did last longer than 42 days, the number of explosions would have been correspondingly reduced if steel pipes had been used instead of copper.

But—and this is the point which should not be overlooked—it is highly probable that the cast-iron valves to which these steel pipes would have to be attached would have fractured at an early date, because the resisting moments of steel pipes are 1.56 times greater than those of copper pipes of the same dimensions, and even copper pipes are occasionally strong enough to fracture the cast-iron valves to which they are attached, as is evident from the following Board of Trade reports:

No. 389. A copper pipe with fairly large bends broke the neck of the valve-chest to which it was attached.

No. 556. The thrust on an expansion-gland acting at the end of a copper pipe as a lever broke the neck of the valve-chest to which it was attached.

No. 971. A copper pipe attached to the end of a combined expansion gland, stop valve and throttle-valve casing broke the latter.

No. 1072. A copper pipe broke the cast-iron neck of a steam chest to which it was attached. The other end of the pipe formed part of an expansion gland which was attached to the engine whose lateral motion was the cause of the fracture.

No. 1177. A copper U-bend between the boiler and its engine acting on the end of a throttle-valve casing broke it.

No. 1572. The thrust of an expansion gland acting at the end of a copper bend broke the valve-casing to which it was attached.

In the following cases the pipes were of wrought iron:

No. 1230. A straight wrought-iron pipe between an expansion gland on the engine and a short cast-iron bend on the boiler stop-valve broke the neck of the latter.

No. 1404. A straight iron pipe which ended in an expansion joint broke the neck of the valve-casing to which it was attached.

The following rather unusual failures may be due to bad material, but seeing that they occurred both with sheet-copper, solid-drawn and electro-deposited pipes it is not unlikely that they were due to fatigue stresses. However, as all these cracks are along the neutral line of the copper bends where there are no bending stresses, but where the shearing-fatigue stresses are maximum, it is not unlikely that these alternating shearing stresses were relatively more intense than the bending stresses near the flanges. It should also be remembered that the fatigue limit for shearing stresses is only ± 2.5 tons per sq.in.

No. 1231 deals with a sharp bend of sheet copper 3.55 in. external diameter which cracked near the brazing line, which is also the neutral line of the bend. The bend was eight years old when it failed.

No. 1262 deals with a bend of sheet copper 10.2 in. external diameter which cracked near the brazing line like the above-mentioned bend. This pipe failed after sixteen months' work.

No. 1662 deals with a bend of solid-drawn copper 6½ in. external diameter which failed along the neutral line after three years' work, when it was repaired and annealed, but it failed again after seven years.

No. 1839 deals with an expansion bend of solid-drawn copper 5.42 in. external diameter which failed along the neutral line after nine years' work. Locally the tenacity was reduced to 5.6 tons with no elongation.

No. 1882 deals with a bend of solid-drawn copper 5.2 in. external diameter which failed along the neutral line after three years' work. It had probably been damaged locally while being repaired. Locally the tenacity was reduced to 7 tons with 1.5 per cent. elongation.

No. 2110 deals with an expansion bend of solid-drawn copper 5.4 in. diameter which failed along the neutral line after four and one-half years' work.

No. 2140 deals with an expansion bend of solid-drawn copper 6½ in. external diameter which failed along the neutral line after six years' work.

No. 986 deals with a bend of electro-deposited copper 3⅞ in. external diameter which failed along the neutral line after three years' work.

No. 1383 deals with a bend of electro-deposited copper 4.8 in. in external diameter which failed along the neutral line after seven years' work, close to a repair sleeve which had been brazed on three months before the explosion.

No. 1736 deals with a bend of electro-deposited copper 3.8 in. in diameter which failed after one year's work. The tenacity was locally reduced to 12.5 tons with 5 and 8 per cent. elongation.

No. 1770 deals with a bend of electro-deposited copper 5.4 in. in external diameter which failed after two years' work. The tenacity was reduced from about 13.5 tons with 45 per cent. elongation to between 9 and 10 tons with 5 to 7 per cent. elongation.

No. 2163 deals with an expansion bend of electro-deposited copper 6 in. external diameter which failed along the neutral line after six years' work.

If, as seems probable, the above 12 failures (about 8 per cent. of the total) were due to sheer fatigue stresses, which are severest along the neutral lines of beams, they would indicate that the bends had been subjected to more complicated forces than have been assumed when dealing with the other failures, but in the absence of any details about the relative movements of the engines and boilers it is fruitless to venture on any estimates, except to say that the formula for torsion fatigue stresses should be applied to these cases and that the stresses which are due to the internal steam pressures should not under any circumstances be overlooked.

While studying those Board of Trade reports which seemed to have a bearing on the present question it was noticed that many copper pipes had failed shortly after being annealed, although until then they had worked satisfactorily for years. This experience would suggest either that annealing does not remove the effect of fatigue stresses or that, if carried out injudiciously, it changes tough copper into a brittle material. In the following list of reported cases the numbers in parentheses denote the periods in months which elapsed between the dates of annealing and of failure:

Pipes of Brazed Sheet Copper.—Nos. 1922 (4), 1210 (5), 1021 (6), 2105 (17), 1011 (19), 1443 (23).

Solid-Drawn Copper Pipes—Nos. 1839 (½), 1926 (2), 1709 (5), 1327 (6), 1327 (8), 1993 (9), 1187 (10), 2003 (21), 2110 (36), 1898 (48).

Electro-Deposited Copper Pipes—Nos. 1164 (3), 1501 (12), 970 (12), 1610 (19).

The average life of a copper pipe after being annealed seems to be about one year for each one of the above three groups, but as already suggested these cases do not prove that annealing is or is not a remedy for fatigued copper. This experience as regards copper does not apply to steel pipes.

As a safeguard against fatigue stresses in steam-pipes expansion glands are sometimes fitted, but they are not always applied where wanted; they sometimes stick fast, and if badly designed the pipes blow out of their sockets.

This latter class of accidents is illustrated in reports Nos. 779, 1702, 2246.

Pipes which stuck fast in their sockets and did not take up the movements are to be found in reports Nos. 283, 1296, 1404, 1666, the last being a doubtful case.

In the following cases the thrusts of the pipes in the glands acting on long bends fractured these near the roots or the glands had stuck fast and the fractures were due to fatigue: Nos. 556, 1113, 1187, 1207, 1230, 1343, 1489, 1572, 1583, 1605, 1609, 1852, 1916, 1978. These are mostly marine cases.

In the following cases the expansion glands neither prevented the pipes from fracturing nor did they cause the fractures: Nos. 169, 584, 971, 1011, 1035, 1056, 1072, 1109, 1172, 1185, 1214, 1264, 1398, 1461, 1515, 1537, 1556, 1747, 1771, 1899, 2006. About half of these cases occurred on steamers.

## The New York Central Wins the Harriman Medal

At the annual meeting of the American Museum of Safety held in the United Engineering Societies Building, 29 West Thirty-ninth St., New York City, Feb. 10, 1915, the E. H. Harriman memorial gold medal for the American steam railway making the best record in accident prevention and industrial hygiene affecting the public and its own personnel during the year ending June 30, 1914, was awarded to the New York Central R.R. The award was made to this road for its record on the New York Central & Hudson River R.R. prior to its consolidation with the Lake Shore. The medal was offered by Mrs. E. H. Harriman to be awarded through the American Museum of Safety. The committee of award consisted of: Arthur Williams, president American Museum of Safety; Samuel O. Dunn, editor "Railway Age Gazette"; Prof. Alexander C. Humphreys, president Stevens Institute; Hon. Chas. P. Neill, former U. S. Commissioner of Labor; and Hon. Edgar E. Clarke, member Interstate Commerce Commission. The medal was received on behalf of the railroad by Alfred H. Smith, president. The silver medal was awarded to the operating department, and the bronze medal to Dennis Joseph Cassin, who had been an engineer on the Central since 1867. He had never had an accident.

## The Overloading of Safety Valves

The formal Board of Trade inquiry in connection with the terrible boiler explosion that occurred at the Thornhill Iron & Steel Works, Dewsbury, on Aug. 10 last, causing the death of eight men, and more or less serious injury to 17 others, provides a lesson which it is to be hoped will be taken to heart by every boiler attendant in the country, as to the criminal folly of interfering with the action of safety valves. The facts of the case were very simple. The boiler, which was one of eight at the works, all coupled together, was of the Rastrick type, heated by the flames from iron furnaces, and was normally worked at 55 lb. per sq.in.

The works were closed from July 31 to Aug. 10, and when the boilers were started the engineer noticed steam blowing off at the safety valves on No. 4 boiler, and without examining the stop valve or the pressure gage he assumed that the escape of steam was due to some defect of the safety valves—of which there were two loaded by levers and weights—and tried to correct it, first by sliding the weights to the end of the lever, and this proving insufficient, by adding a weight of 50 lb., which, being still inadequate to prevent the escape of steam, was supplemented with another 63 lb. As a matter of fact, which was proved after the explosion, the stop valve was shut and the boiler thus isolated from the others to which it was supposed to be connected, and the escape of steam was due to the steady rise of pressure in the boiler, in which steam was being generated without any outlet, and was being bottled up by the extra load on the valves. There could, of course, be only one end to this incredible madness, and that was reached about two or three hours after the fire was started, when the bursting pressure, which would probably be getting near 200 lb., was reached and instantly converted the whole works into a heap of ruins, killing or injuring nearly everybody in the place.

How anyone with a knowledge of boilers could be guilty of such recklessness as to overload safety valves in this deliberate way, without seeing what the pressure was or making sure that any steam generated had at least access to the safety valves of the other boilers, surpasses belief, and we can well understand the Board of Trade Commissioner, when he heard the frank admissions of negligence at the inquiry, "wondering whether or not he was in a lunatic asylum." There were, of course, no technical questions involved in the explosion, for whatever type of boiler had been used the explosion would inevitably have occurred. The inquiry resolved itself into one of fixing responsibility for the disaster, and in view of the engineer's admissions as to the personal part he played there could be no doubt where it lay. The only excuse he could offer was that he thought the stop valve was open, as it was left open when the boilers were laid off on July 31, but he took no steps to verify this assumption or even to look at the pressure gage before he proceeded to hang on weights practically equivalent to a man sitting on the end of the levers. Who shut the stop valve it was impossible to find out, and as regards responsibility little matters, for the most ordinary precaution should have suggested to the engineer that freedom for escape of the steam generated in the boiler should be provided in some way before such "an act of madness" as the overloading of the safety valves was resorted to.

The question remains, how can the consequences of similar crass ignorance be guarded against in the future? The ordinary lever type of safety valve does, it must be admitted, permit of being easily tampered with and overloaded. Of course, whatever type of safety valve is used there is little to protect it from interference, from reckless ignorance or malignant ingenuity, though a locked-up valve which no one could touch would protect such a fitting to some extent from the former risk, and as the Commissioners, in their judgment, which saddled the responsibility for the explosion entirely on the engineer and the boiler attendant who assisted him, emphasize the necessity of valves which can be protected from any interference being adopted, it is possible we may before long see some Board of Trade regulation of this kind imposed on all steam users.—"The Mechanical Engineer," Manchester, Eng.

## Elimination of Smelter Smoke

With the idea of bringing about a better understanding between the metallurgical industry and agriculture as to the troublesome smoke problem at smelting and ore-roasting plants, the United States Bureau of Mines has just issued "Bulletin 84."* Copies may be obtained by addressing the Director, at Washington, D. C. Owners of smelting plants are making every effort to devise ways and means to do away with possible damage and annoyance from great volumes of smelter smoke, comparatively rich in sulphur dioxide and other injurious constituents.

It has been customary to discharge the smelter smoke by very tall chimneys, on the assumption that if the noxious gases are discharged at considerable height they will have opportunity to diffuse more thoroughly and thus become so diluted as to be comparatively harmless, but the efficiency of this method is now being questioned. There is reason to believe that the use of high stacks increases the area to damage, whereas low stacks may intensify the damage but concentrate it within a small area. Probably high chimneys do not serve their purpose as well as was anticipated, and the better method may be to dilute the smelter smoke and discharge it from a number of low stacks.

## Massachusetts Electric Rates Discussed

A battle royal on the subject of electric rates was started on Feb. 5 before the Committee on Public Lighting of the Massachusetts Legislature, which is considering House Bill No. 346, relative to the prices to be charged for electrical energy by central stations. The bill was brought before the committee on petition of the New England Power League, an organization formed about three years ago by manufacturers, business houses, engineers of isolated plants and others interested in the economical use of power. Ernest Stevens, chief engineer of Riverbank Court Hotel, Cambridge, Mass., led the advocates of the bill, which provides that no public-service corporation shall be allowed to sell electricity at less than 5 per cent. above the cost of production and distribution, that the maximum price charged for electricity shall not exceed 25 per cent. over and above the cost of production and distribution, and that the Board of Gas and Electric Light Commissioners shall have power to determine such costs after a thorough examination of all books and properties belonging to such companies.

The principal evidence on behalf of the bill was offered by Thos. W. Byrne, consulting engineer, of Boston, who contended that 90 per cent. of the users of electricity purchase energy at the maximum price and that these small users are charged at least five times as much per kilowatt-hour as the large consumers of power, who easily buy electricity at two cents or less per kilowatt-hour. The speaker urged that the central-station policy is to "charge what the traffic will bear," and said that the National Electric Light Association at its Philadelphia convention in 1914 had gone on record in support of the principle that the value of central-station service was in a large measure determined by the ability of the consumer to install a private plant.

Mr. Byrne contended that the basis of rates should be a fair return on the investment and advocated a valuation of all existing electric-lighting properties in the state by the Gas and Electric Light Commission, for the purpose of checking up the reasonableness of the rates now in force. He pointed out that in the decision of the board in the Worcester street-lighting rate case, the commission had called attention to the power of the company to dictate prices to the small consumer. Members of the Power League feel that present

*The suggestions contained in this bulletin may also be applicable to the power-plant smoke problem.—EDITOR.

central-station rates in various cities of the state are discriminatory, and favor requiring the commission to set forth its views upon the price differences, if any, which should be allowed between lighting and power rates, and between residential and other users, as related to the quantity of energy purchased and as affected by long and short periods of use.

## Available Water Power in United States

According to recently compiled figures made by the U. S. Geological Survey, the total available water power in the United States amounts to about 200,000,000 hp., of which only 6,000,000 is developed. The total available is estimated on the basis of practicable maximum storage of waters possible by the construction of dams and reservoirs. Without storage, the available water power is placed at only 61,678,000 hp., of which the present development is about one-tenth. The water powers as listed by the Geological Survey are distributed in the several states and sections of the country as follows:

| | |
|---|---|
| **North Atlantic States:** | |
| Maine | 971,000 |
| New Hampshire | 295,000 |
| Vermont | 206,000 |
| Massachusetts | 273,000 |
| Rhode Island | 16,000 |
| Connecticut | 164,000 |
| New York | 2,037,000 |
| New Jersey | 127,000 |
| Pennsylvania | 821,000 |
| | 4,910,000 |
| **South Atlantic States:** | |
| Delaware | 13,000 |
| Maryland | 146,000 |
| Dist. of Columbia | 13,000 |
| Virginia | 1,044,000 |
| West Virginia | 1,261,000 |
| North Carolina | 1,050,000 |
| South Carolina | 812,000 |
| Georgia | 752,000 |
| Florida | 16,000 |
| | 5,107,000 |
| **North Central States:** | |
| Ohio | 213,000 |
| Indiana | 141,000 |
| Illinois | 414,000 |
| Michigan | 352,000 |
| Wisconsin | 804,000 |
| Minnesota | 593,000 |
| Iowa | 458,000 |
| Missouri | 195,000 |
| North Dakota | 248,000 |
| South Dakota | 90,000 |
| Nebraska | 439,000 |
| Kansas | 323,000 |
| | 4,270,000 |
| **South Central States:** | |
| Kentucky | 236,000 |
| Tennessee | 913,000 |
| Alabama | 1,132,000 |
| Mississippi | 75,000 |
| Louisiana | 2,000 |
| Arkansas | 73,000 |
| Oklahoma | 250,000 |
| Texas | 661,000 |
| | 3,342,000 |
| **Western States:** | |
| Montana | 5,197,000 |
| Idaho | 3,080,000 |
| Wyoming | 1,566,000 |
| Colorado | 2,036,000 |
| New Mexico | 527,000 |
| Arizona | 2,038,000 |
| Utah | 1,581,000 |
| Nevada | 331,000 |
| Washington | 10,376,000 |
| Oregon | 7,935,000 |
| California | 9,382,000 |
| | 44,049,000 |
| **Summary of States:** | |
| North Atlantic | 4,910,000 |
| South Atlantic | 5,107,000 |
| North Central | 4,270,000 |
| South Central | 3,342,000 |
| Western | 44,049,000 |
| Grand total | 61,678,000 |

## Fatal Sawmill-Boiler Explosion

On Jan. 20 at about 10 a.m. the boiler of a portable sawmill near Beverly, Mo., exploded, killing two and seriously injuring another. A father and his four sons were operating the sawmill on the lowlands of the Missouri River. The engine had been stopped to make some adjustment to the saw. Two of the boys had just left for home near-by, and the other two, aged 7 and 18 years, respectively, were in front of the boiler.

The explosion killed the two boys instantly, disfiguring them almost beyond recognition. The father was found in the underbrush near-by, severely scalded and unconscious. It is believed that he will recover. The boiler was blown through a shed and across a boggy creek for a distance of about 300 ft. from its foundation, striking the ground twice before it finally stopped.

The boiler was of the locomotive type 11½ ft. long with firebox 30x48 in. The front part of the crown and sides of firebox were forced down nearly to the bottom of the furnace. This was the only part that gave way, the tubes, shell and outer firebox sheets remaining intact. The firesheets and stay-bolt ends were badly pitted and eaten away by corrosion, so that the stay-bolts had very little hold. At some parts of the blowoff opening the plate was less than one-sixteenth of an inch thick.

The safety valve and steam gage had not been found up to the time of writing this, as the ground was covered with several inches of snow that had fallen the following night. The inside of the boiler seemed clean. The water column and connections were clear so that it showed the true water level. The injured man claims that there was plenty of water in the boiler just before it exploded.

The owner bought the second-hand boiler about a year ago, when he was told not to carry over 80-lb. pressure. From the appearance of the boiler it ought not to have been used and should have been in the scrap pile.

This is the third explosion of old boilers that has occurred in this vicinity in the last three years, which goes to show the great need of state boiler inspection and engineers' license laws.

## Recent Court Decisions

Digested by A. L. H. STREET

**Assumption of Risk by Employee**—An employee of a power company who was directed to make repairs on a dam while water and ice were running over it assumed the risk of being swept from the dam by the force of the stream, according to a late decision of the Maine Supreme Judicial Court, announced in the case of Monk vs. Bangor Power Co., 92 "Atlantic Reporter," 617.

**Negligent Operation of Boilers**—When negligence of an engineer leads another employee of a common employer to believe that an explosion has occurred or is imminent, and such other employee is injured in attempting to avoid the danger apprehended, the employer may be held responsible in damages, unless the "fellow-servant rule" happens to be applicable. This statement is warranted by a late decision of the Indiana Supreme Court, in the case of Stringer vs. Vandalia R.R. Co. (106 "Northeastern Reporter," 865), wherein defendant was held liable for injuries sustained by a brakeman leaping from a locomotive after the engineer had permitted the crown-sheet of the boiler to run dry and then suddenly turned water on it, causing the crown-sheet to fall, under circumstances which naturally tended to make the brakeman suppose that an explosion had either occurred or was imminent.

## PERSONALS

Edward P. Burch, E. E., has opened an office as consulting engineer, in the Dime Bank Building at Detroit. General practice is contemplated, with specialization in mechanical and railway work and in property valuations.

Dr. Robert Grimshaw, one of the early editors of "Power" and the only living charter member of James Watt Association No. 7, N. A. S. E., of New York, attended the Feb. 13 meeting of that association. Dr. Grimshaw is on a brief visit to the United States, having lived for many years in Germany.

Guy E. Marion, secretary-treasurer of the Special Libraries Association, has severed his connection with Arthur D. Little, Inc., the well known chemists, engineers and managers, of Boston, where he has been located for the last five years in charge of their information department. He has offices in the Tremont Building, Boston, with W. H. Manning, landscape designer.

William W. Cole, of 43 Exchange Place, and Arthur S. Ives and Rolland A. Davidson, composing the firm of Ives & Davidson, of 84 William St., announce the formation of a partnership for the general practice of engineering, under the firm name of Cole, Ives & Davidson, with offices at 61 Broadway, New York. Especial attention will be given to investigations and reports for financial interests, inventories and valuations of public utility or industrial properties and design, installation or management of power plants of all descriptions.

Walter N. Cargill has been appointed superintendent of power and lines of the Rhode Island Co., with headquarters at Providence, and will take up his new work on Apr. 1. For eight years he was in charge of engineering, construction and operation in the one substation and 10 power stations of the lines north of Boston now comprising the northern portion of the Bay State Street Ry. He resigned in 1911 to join the enginering staff of the Stone & Webster Engineering Corporation, where he has since been occupied with investigations, appraisals and problems of a mechanical character in connection with the generating plants designed, examined or operated by the organization.

Lyndon F. Wilson, vice-president of the Railway List Co., Chicago, has resigned to become vice-president of the Bird-Archer Co., New York, manufacturers of boiler compounds,

effective Apr. 1, 1915. He was born at Rush Lake, Wis., Nov. 4, 1883. He was educated at Ripon College, Lawrence University and the University of Wisconsin, and after some general machine-shop and power-plant experience, became an engineer in the service of the United States Government (Department of the Interior), passing examinations in steam, electricity, and heating and ventilating. After one year in this service, he joined the engineering department of the Western Electric Co. and was so engaged until the fall of 1908, when he became mechanical department editor of the "Railway Review," Chicago. In the spring of 1909 he became editor of the "Railway Master Mechanic" and was subsequently given editorial charge of "Railway Engineering," both being published by the Railway List Co. He was promoted to the vice-presidency of this company in the summer of 1913. After Apr. 1, Mr. Wilson will be located in the Chicago office of the Bird-Archer Co.

## NEW PUBLICATIONS

COAL SAMPLING AND ANALYSIS—Technical Paper 76, of the Bureau of Mines, Department of the Interior, is a collection of notes on the sampling and analysis of coal, by A. C. Fieldner. Copies may be had free by applying to the Director of the Bureau of Mines, Washington, D. C.

GEORGE WESTINGHOUSE—To those who did not know him personally, a reading of the Tribute, by Arthur Warren, will give an idea of the elements of his greatness and success, and of the fullness of the life which he lived. Mr. Warren's association with the master was intimate and of long duration, and his Tribute is an evident labor of love.

PENNSYLVANIA RAILROAD has issued a booklet, for distribution at the Panama-Pacific Exposition, describing its activities and exhibit at the Fair and containing a map of the entire system, which, it is claimed, serves 52 per cent. of the population of the United States. It also contains illustrations of the proposed Union Station in Chicago, the main span of the East River bridge, and a model of New York City. A photograph of the last is also reproduced in colors on the cover page. This model shows the city just as if one were looking at it from an aëroplane. It reproduces faithfully not only the main physical features of Manhattan Island and the surrounding country and water courses, but the prominent buildings, the streets, the bridges spanning East River, the parks, and the squares.

CENTRIFUGAL PUMPS—What is probably the most complete commercial publication devoted solely to centrifugal pumps is being distributed by the De Laval Steam Turbine Co., of Trenton, N. J. This book of 298 pages contains over 300 illustrations, including centrifugal pumps for all capacities and heads and for motor and steam-turbine drives, diagrams showing the "characteristics" of such pumps and explaining the relations between impeller-blade angles and characteristics, interior views and views of parts showing the construction, views showing the method of manufacture by the use of limit gages and methods of testing, installations of pumps for various services, also numerous illustrations of the DeLaval reducing gear employed to allow electric motors, water turbines, steam engines and steam turbines to operate at the most economical speed when driving a centrifugal pump. The text matter is divided into chapters under such headings as, "The Introduction of the Centrifugal Pump and the Work for Which It is Adapted"; "Features to be Considered in Selecting Centrifugal Pumping Equipment"; "The Use of the Characteristic Curve"; "Methods of Testing Centrifugal Pumps"; "System of Manufacture for the Production of Interchangeable Parts"; "Details of Design and Construction of Single-stage and Multi-stage Pumps"; "The Speed Question, Particularly Relating to Steam Turbine-Driven Centrifugal Pumps"; "Helical Speed-Reducing Gears"; "Motor and Belt Drives"; "High-Duty Steam Turbine-Driven Pumps as Compared with Reciprocating Pumping Engines for Water-Works Service"; "The Adaptation of Pumps for Circulating Condenser Water, Feeding Boilers and other Steam Power-Plant Service"; "Drainage and Irrigation Pumps"; "Hydraulic Pressure and Elevator Pumps"; "Pumps for Marine Uses, Mining Service, Fire Service and Hot Water and Brine Circulation", etc. Tables and charts are given for determining the resistance of pipes and the relation between heads and spouting velocities. The investigation of the pumping problem, together with drawing up of specifications for centrifugal pumps, are also treated at some length. The chapters on "Pump Characteristics" will prove more valuable to the pump user than many of the more technical treatises. The chapter on "Water Works Pumps," showing that under many conditions the centrifugal pump can handle water at a cost 20 to 40 per cent. lower than it can be handled by reciprocating pumps, because of the lower fixed charges, it is thought will be a revelation to many who have not recently given this matter consideration.

## BOOKS RECEIVED

VALVE GEARS. By Charles H. Fessenden. McGraw-Hill Book Co., New York. Cloth; 170 pages; 6x9¼ in.; 171 illustrations. Price $2.

THE "MECHANICAL WORLD" POCKET DIARY AND YEAR BOOK for 1915. The Norman Remington Co., Baltimore, Md. Cloth; 439 pages, 4x6¼ in.; illustrated; tables. Price 50 cents.

THE "MECHANICAL WORLD" ELECTRICAL POCKET BOOK for 1915. The Norman Remington Co., Baltimore, Md. Cloth; 303 pages, 4x6¼ in.; illustrated; tables. Price 50 cents.

THE DESIGN OF STEAM BOILERS AND PRESSURE VESSELS. By George B. Haven and George W. Swett. John Wiley & Sons, New York. Cloth; 416 pages, 6x9¼ in.; 197 illustrations, including several plates; tables. Price $2.50.

## TRADE CATALOGS

D. G. C. Trap & Valve Co., Inc., Fuller Building, New York. Folder. Brown steam trap. Illustrated.

De Laval Steam Turbine Co., Trenton, N. J. Catalog B. Centrifugal pumps. Illustrated, 298 pp., 6x9 in.

Pelton Water Wheel Co., 90 West St., New York. Bulletin No. 8. Water wheels. Illustrated, 64 pp., 6x9 in.

The Terry Steam Turbine Co., Hartford, Conn. Bulletin No. 19. Centrifugal pumps. Illustrated, 64 pp., 6x9 in.

L. J. Wing Mfg. Co., 352-262 West 13th St., New York. Bulletin No. 27. Turbine Blowers, Type E. Illustrated, 20 pp., 6x9 in.

Gas Engine & Power Co. and Chas. L. Seabury & Co., Morris Heights, N. Y. Catalog. Seabury water tube boiler. Illustrated, 46 pp., 6x9 in.

Schutte & Koerting Co., 12th and Thompson Sts., Philadelphia, Penn. Sectional Catalog. Heat transmission apparatus. Illustrated, 8½x11 in.


# Classified Ads

**Positions Wanted,** 3 cents a word, minimum charge 50c. an insertion, in advance **Positions Open,** (Civil Service Examinations), **Employment Agencies** (Labor Bureaus), **Business Opportunities, Wanted** (Agents and Salesmen—Contract Work), **Miscellaneous** (Educational—Books), **For Sale,** 5 cents a word, minimum charge, $1.00 an insertion.

Count three words for keyed address care of New York; four for Chicago Abbreviated words or symbols count as full words.

Copy should reach us not later than 10 A.M. Tuesday for ensuing week's issue Answers addressed to our care, Tenth Ave. at Thirty-sixth Street, New York or 1144 Monadnock Block, Chicago will be forwarded (excepting circulars or similar literature).

No information given by us regarding keyed advertiser's name or address.

Original letters of recommendation or other papers of value should not be inclosed to unknown correspondents. Send copies.

**Advertisements calling for bids,** $3.60 an inch per insertion. P

## POSITIONS OPEN

AN EXPERIENCED CENTRAL-STATION ENGINEER required to take charge of a 4000-kw. steam and electric plant, containing turbine- and engine-driven A.C. and D.C. generators, water-tube boilers and stokers; must be particularly well versed in steam economy; plant located 50 miles from Chicago; salary $1500 per year; only a thoroughly competent and well recommended man need apply. P. 430, Power, Chicago.

## Civil-Service Opportunities

*Competitive examinations for the civil-service positions named below will be held on or up to the dates given. For detailed information, write the addresses specified.*

ELECTRICAL ENGINEER (male); $200-$300 per month; for vacancy in the Accounting and Engineering Dept. of the Illinois Public Utilities Commission. Write to the State Civil Service Commission, Springfield, Ill.

DRAFTSMAN (male); $75-$100 per month; examination Mar. 6; for vacancy in the Accounting and Engineering Dept. of the Illinois Public Utilities Commission. Write to the State Civil Service Commission, Springfield, Ill.

GAS ENGINEER (male; $250-$333.33 per month; for vacancy in the Accounting and Engineering Dept. of the Illinois Public Utilities Commission. Write to the State Civil Service Commission, Springfield, Ill.